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ABSTRACT

Intended for use by California policy makers and educators, this report examines the link between elementary secondary education and the preparation of people for a high-technology future. It describes engineer and technician job projections in high-technology industries, explores the capacity of California to meet the demand for workers in those industries, and, to the extent that it is understood, explains the relationship between K-12 science and math education and the jobs of the future. The decline in measured student achievement in areas relevant to the technological revolution is reviewed, as are the factors that are critical to student achievement in these areas: participation in science and math courses; the availability and quality of teachers; the quality of texts, materials, and curriculum; and educational funding. Information is also provided on the use of computers in education; efforts to prepare for the changing economy in other countries and states, including the Soviet Union, West Germany, Japan, North Carolina, and Minnesota; and the employment of women and minorities in high-technology industries. Finally, California's current and possible future efforts to improve science, math, and computer literacy are outlined. A 97-item bibliography is provided. (ESR)

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HIGH TECHNOLOGY AND HIGH SCHOOL

PREPARING STUDENTS FOR CALIFORNIA'S CHANGING ECONOMY

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A PERSPECTIVE ON THE ISSUES

JUNE 1982

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Office of Appropriate Technology

STATE OF CALIFORNIA
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IR011120

State of California
GOVERNOR'S OFFICE
SACRAMENTO 95814

EDMUND G. BROWN JR.
GOVERNOR

916/445-2841

Fellow Citizen:

We must act now to improve science and math education if we are to meet the challenge of our changing economy.

California's future economic prosperity depends to a large extent on the ability of our people to adapt to an information-based computer-driven economy. Vast numbers of existing jobs are being eliminated, while countless new jobs are being created. The technological revolution is already touching most Californians' daily lives through the use of advanced electronics in our banks, vehicles and homes.

We must ready ourselves to take full advantage of the opportunities presented by technological change. Preparing for these changes requires an investment in the people of California, through a commitment to excellence that will sustain our economic health and enrich the quality of our life.

The education of our children is where the preparation begins. This report explores the role that the elementary and high school years play in preparing for the technological future. It assesses the status of today's science and math education. It points out areas of tremendous need, particularly in the training of teachers.

This booklet deserves your careful attention.

Sincerely,

Edmund G. Brown Jr.

EDMUND G. BROWN JR.
Governor

HIGH TECHNOLOGY AND HIGH SCHOOL

Preparing Students for California's Changing Economy

A Perspective on the Issues

JUNE 1982

Office of Appropriate Technology

State of California
Edmund G. Brown Jr., Governor

IRO 111120

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Office of Appropriate Technology
Robert L. Judd Jr., Director

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PREFACE

The technological revolution sweeping the nation is having a special effect on California. Since many of the products used in the multibillion dollar high-technology economy are manufactured in the state, more and more jobs in California are requiring upgraded skills and a greater understanding of technology. Even people not employed directly in high-technology industries need to be comfortable and adept with new technologies due to the ominpresence of these products in the changing society. How they perceive and adapt to these technologies will shape quality of life in California for years to come.

As California prepares to meet the challenge of the changing economy, it must look to its students. This paper, based on existing research, examines the link between elementary and secondary education and the preparation of people for a high-technology future. It describes job projections in high-technology industries, explores the capacity of California to meet the demand for workers in those industries, and, to the extent that it is understood, explains the relationship between elementary and secondary education and the jobs of the future. The report also looks at measures of student achievement in areas relevant to the technological revolution and attempts to assess the factors that are critical to student achievement. Efforts to prepare for the changing economy in other countries and other states are identified in the report, as well as California's own preparations and options for further actions.

This report is an initial effort to draw together information that will be useful as background material to policy makers as they develop a plan to better prepare California's students for their technological future.

OVERVIEW

The New Information Society

The nature of how we process information in our personal and professional lives has changed dramatically in the past 20 years. The technological revolution, which has its roots in California's backyard, has spread through this country and other parts of the world and produced a new multibillion-dollar information economy.

Whether or not we find ourselves among the 200,000 owners of a home computer or the one out of every four clerical employees who by 1985 will work with a word processor, technological change is likely to affect our jobs and the skills we need to do them. Economist Marc Porat speculated that 50 percent of the projected labor force in 1995 -- some 50 million workers -- will be involved in information-related jobs.

And according to figures published last year in Business Week, 45 million existing jobs could be affected by factory and office automation, adding to the radical restructuring of the workforce. Much of the impact, Business Week stated, will occur before the year 2000.

Californians have a special interest in the technological revolution because many of the tools and instruments that are central to the new information economy have been designed and produced in the state. High-technology industries, defined by one Silicon Valley spokesman as, "the using of advanced math, science, and the techniques of physics created since World War II to produce a product," will maintain their rapid job growth. The California Department of Economic and Business Development has estimated

the growth of high-technology jobs at 327,900 from 1980 to 1990, a growth of 51.4 percent over the decade. The highest job growth rate is projected for computer services, from 43,300 jobs in 1980 to 128,300 in 1990. The number of jobs in the instrument field is estimated to grow from 98,600 in 1980 to 124,600 in 1990.

Most of all, jobs in intensive high-technology industries, such as computers, electronic components, biotechnology, aerospace, communication equipment, and instruments, will require from the California workforce many skilled technicians and engineers. The California Employment Development Department (CEDD) recently reported:

> The demand for various occupations varies between industries; nevertheless, it is clear that the need for engineers, skilled craftsmen and people facile with information processing equipment is particularly acute. The increasingly sophisticated nature of American industry requires highly trained, well-educated engineers and technicians. (California Employment Development Department, 1981)

Currently there is a deep concern among industry officials statewide regarding the lack of skilled craftsmen, machinists, technicians and subtechnical personnel who are now needed to fill immediate job openings. The CEDD reports that the need for machinists and tool and die makers already exceeds the available supply, and a Bay Area industry official said recently in the San Francisco Examiner and Chronicle:

> ...the bulk of jobs in the future will be for support personnel who develop and build whatever the engineers and scientists conjure up, competent math- and science-trained entry subtechnical personnel. High school and junior college students are critical to our high-technology economy.

And while California colleges and universities are graduating more and more undergraduate engineers -- from 3,351 receiving Bachelor of Science degrees in 1975-76 to 5,023 receiving them in 1979-80, there is a hot debate in engineering circles whether or not there will be shortages in the future. One professional electronics association is predicting that the 1981-85 job growth for engineers and computer professionals will be 89 percent, while another electrical engineering organization is saying that 70 percent of its members doubt there will be an upcoming engineering shortage.

A recent joint report by the National Science Foundation (NSF) and the U.S. Department of Education (DOE) concluded that at present there are "shortages of trained computer professionals and most types of engineers at all levels," but that by 1990, "the numbers of new engineering baccalaureates should be adequate to satisfy the projected demand for their services."

So, while most conclusions and projections show that the U.S. is not headed for a crisis situation in its preparation of engineers, concern is expressed by governmental, professional, and industrial officials about possible shortages in certain subfields of computer science and engineering.

What has emerged as a serious issue is the shortage of graduate engineering students choosing to remain in the academic world to teach. While some undergraduate engineering programs have six to seven applicants for one space in the freshman class, graduate enrollments have dropped substantially in California and the nation because of the high salaries paid by industry to undergraduates right out of school. A student graduating with an electrical engineering degree, for example, is likely to make $6,000 more at his first job than his professor makes in teaching him. Many people refer to this dilemma as "eating our seed corn."

James Methany, Dean of Engineering at California State University, said recently in Fortune Magazine, "I haven't even bothered to recruit an assistant professor since 1972. The most I can offer a new teacher is $19,000 and that would be insulting, demeaning." The joint NSF/DOE report also expressed concern about the diminishing number of qualified professors now and in the future.

In the Fall of 1980, ten percent of the 16,200 engineering faculty positions in 244 engineering schools in the United States were vacant. There are currently openings for engineering faculty at all of California's public colleges and universities, from 18 openings out of 225 full-time engineering positions at the University of California-Berkeley to 38 openings out of 94 positions at California State University-San Jose.

Competition Overseas

This problem takes on even greater importance when we look at our competition overseas. Other highly industrialized countries are producing many times the number of engineers the United States is, in part because they place a high premium on science and math literacy.

Japan, for example, with a population about half the size of ours, graduated nearly 87,000 engineers last year, compared with 63,000 in the United States. Twenty percent of all baccalaureates in Japan are granted to engineers and about 40 percent of all master's degrees are granted to engineers, figures which have been stable for the past ten years. This compares with a figure of about five percent at each degree level in the United States, according to statistics published by the NSF/DOE.

Michael Kirst, Professor of Education at Stanford University, recently visited Japan at the invitation of the Japanese Ministry of Education. He said that overall achievement scores in Japan in science and

math are the highest in the non-communist world, especially with respect to problem-solving skills.

Izaak Wirszup, a leading observer of Soviet education, has reported recently that the Soviet high school student "is required to complete five years of physics, four years of chemistry, one year of astronomy, five and a half years of biology, and so on down the list that would empty America's high schools via the dropout rate."

In a gap that seems to keep widening, the USSR in 1974 had nearly twice the number of engineers as did the United States, while the number of engineering degrees granted in 1960 in the Soviet Union was 102,800, compared with 37,800 degrees granted in the United States. In recent years, the number of engineering graduates in the USSR has jumped to 300,000, compared with 63,000 in the United States.

Preparing for the Future

The elementary and high school years are important to preparing people for working and living in a technologically complex and changing world. For professional workers in high-technology industries -- engineers and computer scientists, for example -- a strong high school background in math and science is critical. Research has shown that:

- High school science and math abilities are not only strong predictors of whether or not a high school student will follow through with plans to work in a science-related field, they are also, according to the American Institutes for Research, "surprisingly high" predictors of whether or not a student will succeed in that career.

- The number of math courses taken by a student has been shown to correlate directly with how well the student scores on standardized math tests.

- Students with more math and science coursework in high school have been shown to be more likely to choose science or other quantitative fields in college, as have students with higher math test scores.

Nonprofessional workers in high-technology fields will find the amount of math and science they need varies depending on which of the wide range of jobs they enter. Assemblers of electronic circuits, for example, use no more math and science on the job than do assembly-line workers in any other industry. Microfilm technicians, a mid-level job, need about a tenth-grade level of mathematics. But many of the more highly skilled technical jobs in high-technology industries, such as electronic technicians -- jobs for which there is high demand for workers -- require degrees from community colleges or vocational institutes. People in training and placement for high-technology jobs have said that a strong background in high school math and science (especially physics) is important to success in vocational school and on the job.

Workers not directly employed in high-technology industries also need to achieve some level of technological literacy in high school. A great number of jobs will be affected indirectly by the technological revolution. Dr. Stanley Pogrow of the University of Arizona recently pointed to the future need for clerical workers to engage in nonroutine interactions with computers, the declining ratio of assembly line workers to skilled employees at General Motors, and a statement made by a representative of Pacific Gas and Electric Co. that 80 percent of its new employees need to be computer literate. He remarked:

> Such employment trends suggest that education is going to be even more of a prerequisite for employment in the future, and that a significant portion of the workforce is going to have to acquire new work skills and habits in the near

> future. Much of these new skills will relate to using technology, and a large percentage of the growing non-manufacturing workers are going to have to begin to perform increasingly sophisticated technical operations.

Even the general public has a need for technological literacy. A recent report from the Minnesota Educational Computing Consortium pointed out that understanding computers enables people to use and influence the design of computer-based social services and to develop informed opinions regarding computer applications that have political, economic, and social implications. Academic research also shows that the more knowledgeable a populace is about science and technology, the more likely it is to favor research and development in these fields.

Technological Literacy and Student Achievement

How well are American students preparing in high school to meet the demands of the changing economy? The data available to evaluate readiness is unfortunately limited to achievement test scores and the number of students enrolling in remedial math courses. Inherent in these data are the often-discussed problems of using achievement tests to measure skills and knowledge.

An additional problem is that most standardized tests measure aptitude or basic skills. Most do not measure the more sophisticated substantive knowledge and skills needed by students going on to college, nor do they evaluate the acquisition of technological literacy or practical job skills of students who do not intend to pursue professional high-technology careers.

Reviewing the evidence of student achievement in California and nationwide over time reveal the following:

- Scores in reading, math, and language skills for sixth and twelfth graders in California declined from 1969 to the mid or late 1970's, when some scores began to turn around. The math scores of sixth graders have been improving since 1974, while the math scores of twelfth graders have been improving since 1976.

- Third- and sixth-grade students in California performed above national medians on achievement tests, while the evidence regarding twelfth graders in comparison with the nation is mixed.

- Nationwide, science and math test scores among 9-, 13-, and 17-year-old students declined from the early 1970's through the last evaluation in 1978. The decline was most pronounced in the higher age groups.

- SAT scores declined significantly among both California students and students nationwide since the late 1960's, with a recent upswing in California scores and continuing decline or no change in national scores. The mean California score currently exceeds the national average.

- The gap in SAT scores between students intending and not intending to pursue science and engineering fields in college is widening.

- Scores on the SAT achievement tests have declined since the late 1960's among California students. They have been more stable among those students taking the achievement tests nationwide. A larger percentage of California students take both the SAT and the SAT achievement tests than take them nationwide, with the result that more marginal students take the test in California and therefore bring down California's average scores.

- The performance of young adults ages 25 to 36 on tests of scientific knowledge declined between 1973 and 1977.

- Coursework in pre-calculus at the college level is on the rise. A nationwide study found that enrollment in these courses increased by ten percent between 1970 and 1975 while enrollments in colleges and universities increased less than three percent.

Teacher Shortages

Factors that are critical to student achievement are easier to evaluate than student achievement itself and are probably more telling. Teacher knowledge and abilities have long been known to be important to student achievement. Statistics on the current availability and qualifications of teachers of math and science paint a frightening picture:

- In California, 170 long-term emergency credentials were issued in math for 1980-81 because of the shortage of math teachers. A teacher does not necessarily need college credits or experience in the subject area in which an emergency credential is issued.

- The shortage is getting worse, if the Los Angeles Unified School District, the hardest hit with the shortage in the state is any indication. In 1981-82, 333 long and limited term emergency credentials were issued compared with a total of 169 credentials of both types issued in 1980-81.

- Recent national studies show math and physics to be the areas of greatest shortfall in teacher supply, with shortages that have grown progressively worse since 1976.

- Another recent national survey shows over 50 percent of newly-employed science teachers as being employed on an emergency basis. The figure is a whopping 84 percent for the Pacific states.

- A 1981 survey showed that of a sample of almost 60,000 teachers who teach science 50 percent of the time or more, 18 percent were non-science majors. Twenty-six percent of these 18 percent were math majors, 24 percent were physical education majors, 11 percent were social studies majors and seven percent were home economics majors.

- The shortage of math and science teachers may become worse due to few students entering math and science teaching careers. A recent survey by the University of California-Berkeley's Department of Education showed only 92 students currently enrolled in math and science teaching majors in all the public universities in the state with the exception of San Jose State -- a number that is expected not nearly to fill the gaps left by teachers retiring and leaving their jobs for industry, where salaries, status, and other benefits are larger than in the teaching profession. A national survey shows five times as many teachers leaving their jobs for industry as for retirement.

- National surveys show declining numbers of science and math teachers being produced in teacher-training programs.

The time spent engaged in learning has been shown by several researchers to be a critical factor in student achievement. In that context, statistics on the percentage of California students who take substantial numbers of math and science courses in high school -- enough to pursue further education leading to professional and technical careers in high-technology industries -- are alarming. It should be noted that these statistics are based on data collected from college-bound students taking

the SAT who voluntarily answered questions about their high school background, and that a larger percentage of California seniors take the SAT than do seniors nationwide. Since the top seniors generally take the SAT, states where a smaller percentage of students take the test have an advantage on mean scores and number of courses taken. In 1980, 57 percent of California males compared with 67 percent of males nationwide took four years of math; 38 percent of California females compared with 50 percent of females nationwide did so. About six percent of male and female California students took three or more years of biology, compared with nearly eight percent of both sexes nationwide. In the physical sciences, only 15 percent of male California students took three or more years compared with over 31 percent of male students nationwide. Only seven percent of female California students took three or more years compared with almost 17 percent nationwide.

A third input to student achievement is textbooks, curriculum, and materials. A 1977 study by Professor Jeanne Chall at Harvard University linked declining difficulty in textbooks to declining scores on the verbal portion of the SAT. While there has been no comprehensive evaluation of science and math texts, anecdotal evidence indicates that textbooks currently in use are about two grade levels lower than those used 10 to 15 years ago.

Current course offerings, the National Science Foundation study found, may not be in keeping with the need for technological literacy among the majority of students who will not pursue professional or highly-skilled technical careers. These students need more general information on computer use, information on technological change and society, and science and math courses geared to specific job skills.

The use of computers for educational purposes is one way of achieving the dual objective of supplementing teachers and textbooks and introducing

students to a tool they will likely encounter in the working world. The number of computers in classrooms is increasing; currently, about 36 percent of school districts in California have at least one microprocessor. These are used mostly for math, computer literacy, science, and business education courses and career guidance. Nationwide, the number of microcomputers in schools is estimated to be as high as 90,000 with a possible 400,000 being installed by 1985. Research has shown that computer-aided instruction may have a positive impact on student achievement.

Minnesota has established itself as probably the leading instructional computer state in the country with the Minnesota Education Computing Consortium (MECC). Through the MECC, computing facilities are now available to more than 95 percent of Minnesota public school and college students.

Other states are trying other approaches in their efforts to improve the preparation of students for living and working in the high-technology society. For example, North Carolina started a residential public high school for students with high aptitudes for science and math. In its first year with 150 students, the school had the largest number of 1982 National Merit Scholarship semi-finalists of any school in the nation.

Women and Minorities

One common dilemma that all states appear to be experiencing is the very large under-representation of women and minorities in all fields of engineering and science. While the women's share of bachelor's degrees in engineering has risen dramatically in the last ten years, from less than one percent in 1970 to ten percent in 1980, figures published recently in Science magazine show they still have higher unemployment rates and lower salaries than men in all fields of science and math at all degree levels. Median salaries of 1978 science and engineering graduates, published by the

National Science Foundation, showed women earning $12,500, while their male counterparts earned $16,900.

Of the nearly 63,000 graduates who received baccalaureate degrees in engineering nationwide in 1981, all minorities accounted for only 8.3 percent. Blacks, Hispanics, and American Indians, taken as a group, accounted for only 4.7 percent of the total.

California's Efforts to Improve Technological Literacy

In its efforts to improve elementary and secondary school science and math, some exemplary programs in California have addressed the issue of women and minorities. These include the Mathematics-Engineering-Science Achievement Program (MESA), which helps prepare minorities and women for university-level courses in math, engineering, and physical science-related professions through tutoring, career advising, and scholarship incentive awards. EQUALS, a program for women, conducts workshops with educators to help increase the participation of females in mathematics courses.

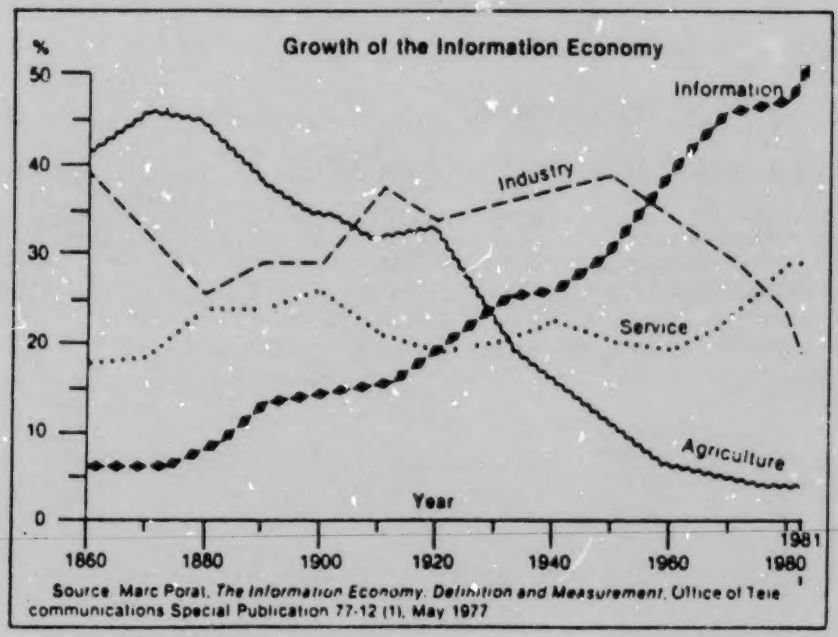
Governor Brown recently proposed "Investment in People" initiatives to the Legislature, with the goal of improving the technological literacy of California's students. Among his priorities are a proposal that local districts require all high school students to take at least three years of math and two years of science. Brown's other proposals include the retraining of current and recently laid off teachers in math, science, and computer instruction. Increasing instructional use of computers at the secondary level and integrating science and technical subjects into other coursework are also included in the Governor's program.

I. THE TECHNOLOGICAL REVOLUTION

Whether we are individually aware of it or not, the technological revolution that has swept through the country has changed our lives. In many of our routine activities during the course of a day -- making a bank transaction, purchasing an airline ticket, selling stock, paying bills -- we are either directly or indirectly involved with some aspect of technological innovation. Some of us may have only minimal direct contact with these changes, but many will have new technologies brought into our homes or will be introduced to them at work.

This technological revolution is complementing and spurring major changes in the American economy and consequently in Americans' jobs. According to economist Marc Porat, the United States ceased being an industrial economy and became an information economy in 1963, when 53 percent of earnings were reported to be in the information sector. Porat said that the information sector grew from 15 percent of the workforce in 1910 to over 40 percent of the workforce in 1970. The percentage of the workforce engaged in agriculture and industry has been declining steadily since about 1920 and 1945, respectively, until in 1980 agricultural workers comprised only about five percent of the workforce and industrial workers comprised about 25 percent. Porat maintained that 50 percent of the projected labor force in 1995 -- some 50 million workers -- will be involved in information-related jobs. See Figure I-1. (Pogrow,1982)

FIGURE I-1



Computers are an integral part of this information economy. Originally, computer buffs were the only buyers of computers. Now industry experts say the customer is too diverse to classify. There are more than one-half million general purpose computers in the United States alone and available computer power is growing at about 40 percent a year. Recent figures show that currently there are 200,000 microcomputers installed in homes, 150,000 in small businesses, 250,000 in science and technology firms and 60,000 in large businesses. A recent Newsweek cover story described the computer explosion like this:

> Five years ago it was a hobbyist's toy. The handful of manufacturers were tiny, garage-shop operations turning out a few thousand machines a year. Now -- with astonishing suddenness -- a multibillion dollar industry has been born. Powerful, versatile personal computers are being used almost everywhere -- on oil rigs and yachts, backstage at rock concerts, and in countless homes and offices. (Newsweek, 1982)

Computers have created a major change in the skills needed by millions of workers. More than one million word processing units have been installed in offices around the country -- an average of one processor for every ten clerical workers at last year's count. By 1985, another 1.5 million are expected to be installed, or one for every four clerical workers. Arthur Luehrmann, founder of Computer Literacy, Co., predicts that, within five years, all jobs will require interaction with computer-based information. (New York Times, 1981)

"Filing skills will be far less important because these machines can store vast amounts of information that can be retrieved with the push of a button," said Bruce Richardson, a market research analyst with the Yankee Group, a Boston consulting firm. The salaries of secretaries with word processing skills are already higher than those who lack such expertise. "The typical secretary earns from $250 to $300 a week while the secretary who has skills in word processing earns at least $50 more," Richardson said. (New York Times, 1981)

A study conducted by Kenneth Kramer and James Danziger of the Public Policy Research Organization at the University of California at Irvine showed that, in 40 polled cities with populations of 50,000 or more, 30 percent of the "countertop bureaucrats" (such as utility clerks) use a microcomputer daily. The study, which polled 2,408 people working in, among other cities, San Francisco, Las Vegas, Stockton, Burbank, and San Diego, also showed that 27 percent of the "street-level bureaucrats" (such as

policemen) use computers on a daily basis. The study's results also showed that only six percent of policy makers use computers on a daily basis, as do eight percent of managers and six percent of professional staff. (Danziger, and Kramer, 1983)

Kramer said he thought the study's results were representative of microcomputer usage by the workforce in larger cities. "Probably by the end of the decade, that 30 percent figure of 'countertop bureaucrats' will be true of all levels in the workforce. By 1990, that percentage will characterize all cities," Kramer stated.

Considering the declining costs of computers, Kramer's forecast is most probably accurate. Along with the 40-percent-a-year growth in computers mentioned earlier come these observations published recently in Science magazine:

> The cost of computers is expected to fall by about 20 percent per year through 1986, although at differing rates in differing years. This, combined with the rising costs of human labor, motivate and ensure the future use of computers. A typical microcomputer that cost $50,000 a few years ago now costs from $3,000 to $5,000 and will be sold for about $500 in another three to four years. (Branscomb, 1982)

The job skills needed for the future are changing not only because of the introduction of computers directly into the workplace but also because automation and robots are predicted to displace current job skills at rapidly increasing rates. Business Week last year published its predictions of 45 million existing jobs being affected — many of them during the next 20 years -- by automation and computer-controlled systems of robots. See Table I-1. Currently, the United States has about 3,200 robots, almost half of which are being used in the auto industry. General Motors alone has more than 450 robots and is planning to have 5,000 in use by 1985 and 14,000 by

1990. The vast majority of auto industry robots, 80 to 90 percent, are used in assembly and preparation of automobiles.

TABLE I-1

JOBS THAT WILL BE AFFECTED BY AUTOMATION

In Factories	Number of Employees	In Offices	Number of Employees
Assemblers	1,289,000	Managers	9,000,000
Checkers, Examiners, Inspectors, Testers	746,000	Other Professionals	14,000,000
Production Painters	185,000	Secretaries & Support Workers	5,000,000
Welders and Flame-Cutters	713,000	Clerks	10,000,000
Packagers	626,000	Total	38,000,000
Machine Operatives	2,385,000		
Other Skilled Workers	1,043,000		

Source: Business Week, 1981.

The Business Week article also discussed the impact of automation and robots on the job skills needed for the future:

> The rapidly developing drive toward the workerless factory — and the automated but still populated office — will affect American jobs and jobholders on a scale unprecedented in modern times. Scholars of automation do not expect this rapid substitution of machinery for human labor to increase unemployment, assuming healthy economic growth. But they do expect a radical restructuring of work, including a devaluation of current work skills and the creation of new ones at an ever-increasing rate. This will result in a fundamental change in most workplaces and an often

> painful adjustment for the workers involved. These changes will require employers to retrain huge numbers of workers. Ultimately, the nation's education system will have to prepare future workers for functioning in an electronic society. (Business Week, 1981)

Growth in High-Technology Industries

Many Californians have a special interest in the technological revolution because of the state's close connections to high-technology industries. The California Department of Economic and Business Development (DEBD) has estimated the growth in high-technology jobs at 327,900 from 1980 to 1990, an advance of 51.4 percent over the decade. (California Department of Economic and Business Development, 1982) The Center for Continuing Study of the California Economy, however, recently estimated total high-technology job growth at 234,500, a 47.6 percent increase over the decade. (Center for Continuing Study of the California Economy, 1981)

Jobs created indirectly by high-technology industries also play an important role in California's employment picture. DEBD predicted last year that for every job directly created by high-technology industries, two will be created indirectly. In the period from 1975 to 1980, the DEBD figures showed that 27 percent of all new jobs in California were created directly or indirectly in high-technology industries and that between now and 1990, some 40 percent of the state's new jobs will depend on growth in the industries.

In understanding the information and statistics concerning the growth of these industries, it is important to note the lack of a clear definition of exactly what employment sectors the high-technology industries include. Officials from different areas within the high-technology industries have varying definitions of the term.

Ned Rasor, president of Rasor Associates, Inc., a Sunnyvale engineering consulting firm, for example, says his gut-feeling definition is "not just bending sheet metal but using advanced math, science, and the techniques of modern physics created since World War II to produce a product." (Rasor, 1982)

Others, such as Bob Noyes, vice chairman of Intel, one of the leading semiconductor companies in Silicon Valley, says that one of his definitions would include the fact that ten percent of the sales made in high technology would have to be put into research and development before it could be classified as being high technology. "I would include the fields of plastics, biotechnology, energy technology, liquification of coal, robotics, aerospace. It would have to include heavy involvement in commercial research and science technology," Noyes said. (Noyes, 1982)

"High technology doesn't have just one definition," Gary Burke, a personnel manager at IBM said. "To most people here it means a state of the art industry which employs highly professional people." (Burke, 1982)

In general, when defining what high technology is, most analysts use the Standard Industrial Classification (SIC) system to classify major economic sectors and follow developments in the areas. These classifications, shown in Table I-2, include Computers, Communication Equipment, Electronic Components, Instruments, and Computer Services. Other classifications include aerospace, biotechnology, photovoltaics, and robotics. Table I-2 shows that high-technology jobs in California are going to increase at an annual compound growth rate of 3.97 percent during the 1980s. This is almost double the rate of increase in total jobs — compound growth rate of 2.24 percent — of the 1970s.

TABLE I-2

CALIFORNIA
HIGH TECHNOLOGY INDUSTRY JOBS

1970-1990
(Thousands)

	1970	1980	1990	Absolute Growth 1970-1990	Annual CGR 1980-1990
Computers	52.8	97.1	163.0	65.9	5.32
Communication Equipment	102.9	130.1	163.3	33.2	2.30
Electronic Components	55.6	123.1	147.5	24.4	1.82
Instruments	50.3	98.6	124.6	26.0	2.37
Basic High Technology	261.6	448.9	598.4	149.5	2.92
Computer Services	11.4	43.3	128.3	85.0	11.47
Total High Technology	273.0	492.2	726.7	234.5	3.97

Source: California Employment Development Department and Center for Continuing Study of the California Economy, 1981.

Table I-2 also shows that the field of computer services is projected to have the highest rate of growth among the individual fields in high technologies. Jobs will nearly triple in that field to 128,300 in 1990 from 43,300 in 1980. In 1972, there were only 11,400 jobs in that field.

The table also shows that in the instrument field the number of jobs will grow from 98,600 in 1980 to 124,600 in 1990, or a compound growth rate of 2.37 percent. Communication equipment jobs will grow from 130,100 two years ago to 163,300 in 1990, an absolute growth of 33,200 jobs.

In a more detailed but slightly different approach to defining growth industries in California, CEDD published a study last year, California's Leading Industries, that identified seven major fields. The statistical data included in the report were to be used to indicate future trends rather than precise estimations of future employment. The seven growth areas, which included information processing, machinery, aerospace, energy, mining, instruments, and biotechnology were determined by examining forecasts made in national business magazines. "Growth" was defined in the publication in terms of changes in profits and sales and not in terms of employment. (CEDD, 1981) See Table I-3 for CEDD's breakdown of the seven growth industries.

For the purpose of further examining the future of high technology in California, projections in four of the seven growth areas from the CEDD study are most often considered high-technology industries, but the aforementioned caveat regarding employment estimations should be considered when reviewing the tables and figures. The job projections are made to 1985 rather than to 1990, as were the previously mentioned projections.

TABLE I-3

CHANGES IN CALIFORNIA EMPLOYMENT IN SEVEN GROWTH INDUSTRIES
(in thousands)

	Percent of Total 1980 Employment	Percent of Total 1985 Employment	1976	1980	1985	Average Percent Change 1976-1980	Average Percent Change 1980-1985
Total, All Industries	100	100	9,223	11,070	12,487	5.0	2.6
Aerospace							
Guided Missile, Space Aircraft & Parts	1.9	1.8	156.1	207.5	221.0	8.2	1.3
Mining	0.4	0.4	34.7	42.9	45.6	5.9	1.3
Machinery (Nonfarm)	1.1	1.1	98.0	125.7	136.2	7.1	1.7
Construction & Related							
Metal Working							
General Industry							
Special Industry							
Other Excluding Electrical							
Instruments	0.9	0.9	67.5	98.6	112.8	11.5	2.9
Information Processing	2.0	2.2	137.1	220.2	280.2	15.1	5.4
Office & Computing							
Electronic Computer and Access							
Energy*	1.1	1.1	124.4	134.5		1.6	

*Estimates for conventional energy sources only.

All data in this chart are meant to be approximations of California industry employment based on ED&R Projections.

Source: California Employment Development Department, 1981.

Information Processing. This field includes computer programming and electronic computing equipment, as defined by this study. Table I-4 shows that in 1980 there were 126,209 people in California working in information processing and in 1985 there are projected to be 165,551, for an average annual growth of 6.23 percent. There are approximately 2,000 electronics firms in California, half of which are located in Silicon Valley. The job breakdown in this field, as seen in the table, also shows that the largest areas of employment in 1985 will be in the areas of clerical work and those people operating machines.

TABLE I-4

COMPUTER PROGRAMMING
+
ELECTRONIC COMPUTING EQUIPMENT

Total	1980	Percent	1985	Percent	1980-1985 Average Percent Change
All Occupations (Including Professional)	126,209	100	165,551	100	6.23
Computer Specialists*	12,626	33.42	16,723	32.13	6.49
Clerical	23,901	18.9	27,327	16.5	2.5
Office Machine Oper.	5,116	4.05	5,795	3.50	2.65
Computer & Periph. Equip.	4,652	3.68	5,797	3.50	2.46
Crafts & Kindred Workers	10,595	8.39	14,129	8.52	3.34
DP Machine Repairers	2,230	1.76	3,723	2.24	13.39
Metal Crafts Workers exc. Mechanics	1,185	0.93	1,523	0.91	5.70
Mechanics, Repairers, Installers	6,302	4.99	9,264	5.59	4.70
Operatives	16,459	13.04	20,456	12.34	4.86
Semiskilled Metal-working	1,659	1.31	1,789	1.07	1.57
Semiskilled Assemblers	9,171	7.26	11,452	6.91	4.97

Source: California Employment Development Department, 1981.

Aerospace. Table I-5 shows that, in 1980, there were 190,105 people working in aerospace in California and it is expected there will be 202,664 in 1985, an average annual change of 1.35 percent between 1980 and 1985. The CEDD report stated that one expansion in this field should be in the production of civilian aircraft, as commercial airlines replace their airplanes. Another significant increase, the report found, probably will come from increased defense spending. The table also shows that the largest portion of people needed in this field will be professional engineers. Large numbers of aircraft mechanics, assemblers, and transport operators will be needed, too.

Instruments. Table I-6 shows that there are currently 91,966 people employed in the professional and scientific instruments field in high technology, and that there will be roughly 102,393 employed by 1985, an average annual growth of 2.27 percent.

Biotechnology. In the CEDD study, officials indicated that it is difficult to estimate the impact of biotechnology on jobs but that it is generally expected "to have as significant an impact on society in the 1980s and 1990s as the microelectronics industry had in the 1970s." The two main genetic engineering firms in California, Cetus Corporation in Berkeley, and Genetech in San Francisco, employ roughly 200 and 700 people, respectively. About 20 percent of the Cetus employees and over 40 percent of Genetech's hold Ph.D. degrees, with most of the remainder being technicians. The labor demand, according to the study, should continue to be high for biologists, engineers, and laboratory technicians.

TABLE I-5

AIRCRAFT AND PARTS

	1980	Percent	1985	Percent	1980-1985 Average Percent Change
Total, All Occupations (Including Professional)	190,105	100	202,954	100	1.35
Crafts and Kindred Workers	44,087	23.19	50,407	24.84	2.87
Construction Crafts Workers	3,869	2.04	4,266	2.10	2.05
Electricians	2,147	1.13	2,293	1.13	1.36
Blue Collar Wkr. Supvr., N.E.C.	9,524	5.01	10.857	5.35	2.80
Metal Crafts Workers, Exc. Mech.	17,499	9.21	20,020	9.86	2.88
Machinists	6,654	3.50	7,286	3.59	1.90
Pattern & Model Makers	1,406	0.74	1,624	0.80	3.09
Sheet Metal Workers, Tinsmiths	2,490	1.31	2,821	1.39	2.66
Tool, Diemakers	5,912	3.11	7,123	3.51	4.10
Mechanics, Repairers, Instal.	11,581	6.09	13,543	6.67	3.39
Aircraft Mechanics	8,307	4.37	10,025	4.94	4.14
Operatives	42,149	22.17	45,771	22.55	1.72
Semiskilled Welders & Flame Cutters	2,224	1.17	2,395	1.18	1.54
Semiskilled Packing, Inspecting	7,694	4.05	8,672	4.27	2.54
Checkers, Examiners, Etc., Mfg.	7,277	3.83	8,283	4.08	2.76
Other Operatives, Exc. Transport	25,968	13.66	28,348	13.97	1.83
Assemblers	17,660	9.29	20,153	9.93	2.82

Source: California Employment Development Department, 1981.

Geographical Distribution of High Technology Growth

In its projections of growth in the 1980s, by economic region, the Center for Continuing Study of the California Economy determined the likely areas of high-technology growth. Highlights of new jobs created due to high-technoloy include the following:

TABLE I-6

PROFESSIONAL, SCIENTIFIC INSTRUMENTS
+
SCIENTIFIC INSTRUMENTS

	1980	Percent	1985	Percent	1980-1985 Average Percent Change
Total, All Occupations (Including Professional)	91,966	100	102,393	100	2.27
Clerical Workers	14,980	16.28	17,311	16.90	3.11
Bookkeepers, Accounting Clerks	1,106	1.20	1,233	1.20	2.29
Expenditors, Prod. Controliers	1,213	1.32	1,546	1.51	5.48
Crafts & Kindred Wkrs.	12,969	14.10	13,896	13.56	2.86
Mechanics, Repairers, Install	1,540	1.67	1,788	1.75	3.22
Other Crafts	3,246	3.53	4,060	3.97	5.02
Opticians, Lens Grind, Polisher	2,076	2.26	2,411	2.35	3.23
Operatives	29,590	32.17	33,998	33.20	2.98
Semiskilled Metalworking	3,744	4.07	4,043	3.95	1.60
Semiskilled Packing, Inspecting	4,671	5.08	5,144	5.02	2.03
Checkers, Examiners, Etc.	2,556	2.78	2,892	2.82	2.63
Other Operatives	15,229	16.56	17,966	17.55	3.59
Assemblers	13,720	14.92	16,034	15.66	3.37
Misc. Machine Operatives	2,142	2.33	2,399	2.34	2.41

Source: California Employment Development Department, 1981.

- o Los Angeles Basin will add nearly 37,000 jobs, or 32.2 percent of the state's growth.
- o High-technology jobs in the Bay Area are expected to grow to 196,000 by 1990.
- o San Diego will increase its number of high-technology jobs by 14,000 during the decade.

- o Sacramento will experience a large growth of new jobs as a result of a new complex developing around Roseville, and Hewlett Packard is expected to create 5,000 new jobs by the mid-1980s.

- o Changes in the Coastal Area (Santa Barbara, Salinas, Monterey, Santa Cruz) are expected to bring 6,000 new high-technology jobs by 1990. (Center for Continuing Study of the California Economy, 1981)

Table I-7 shows jobs in individual high-technology industries for the seven economic regions.

TABLE I-7

CALIFORNIA AND ECONOMIC REGIONS
JOBS IN INDIVIDUAL HIGH TECHNOLOGY INDUSTRIES

1980
(Thousands)

	Computers	Communication Equipment	Electronic Components	Instruments	Computer Services	Total
Los Angeles Basin	40.6	99.9	37.4	52.7	20.2	250.8
San Francisco Bay Area	49.1	20.0	73.0	35.0	16.1	193.2
San Diego SMSA	7.9	7.4	7.7	7.9	3.7	34.6
Sacramento SMSA	0.6	0.1	0.1	0.3	1.1	2.2
Coastal SMSAs	0.8	0.9	2.8	1.8	0.5	6.8
San Joaquin Valley SMSAs	0.0	0.1	0.7	0.8	0.6	2.2
Nonmetropolitan Counties[1]	0.5	1.7	2.7	0.1	0.4	6.4
California[1]	97.1	130.1	123.1	98.6	43.3	493.2

[1] 1979 data used for nonmetropolitan county region only. Therefore, the region totals will not add exactly to the state total. The 1979 data are the most recent reliable estimate of activity in the nonmetropolitan county region. The 1980 SMSA data will be revised slightly in 1982 possibly causing large percentage changes in the residual (i.e. nonmetropolitan region) totals for each.

Source: California Economic Development Department and
Center for Continuing Study of the California Economy, 1981.

II. READINESS FOR HIGH-TECHNOLOGY INDUSTRIES: CALIFORNIA AND THE UNITED STATES

In its conclusions and projections for the future of California's job growth, including jobs in high technology, the state's Employment Development Department summarized the future need for workers.

> The demand for various occupations varies between industries; nevertheless, it is clear that the need for engineers, skilled craftsmen and people facile with information processing equipment is particularly acute. The increasingly sophisticated nature of American industry requires highly trained, well-educated engineers and technicians. (CEDD, 1981)

Technicians or Engineers?

In determining the readiness of the California and national workforce for the projected expansion of high-technology industries and for the jobs that are created indirectly by the new growth areas, one must recognize that although there is a need both for skilled engineers and technicians, the line differentiating between what these two workers do has become blurred, most especially in these relatively new and fast-growing areas mentioned. The lack of a clear definition makes discussion of the supply and demand for workers difficult. What exactly is an engineer and what exactly is a technician? As industry officials have varying definitions of what high technology is, so too do they have varying definitions of what is encompassed by these two occupations. The traditional job responsibilities of engineers and technicians have changed with the recent technological innovations.

The most simplified version of the distinction between the two occupations given by industry officials is that an engineer has a college degree, while a technician is trained either on the job or through a special

training program at an institution. However, no definitive studies have been done determining the number of engineers compared to the number of technicians in the industry. One major factor that would have to be taken into consideration in trying to find that percentage, if a study were done, would be looking beyond the titles of those who are labeled engineers. For example, at IBM, there are employees called customer or field engineers, or technical support engineers, who traditionally need no college degrees to perform their jobs.

Wayne Amacher, chairman of the 8,500-member Santa Clara Valley section of the Institute of Electrical and Electronics Engineers, a nation-wide organization, said that "20 to 30 percent of the labeled engineers are non-degreed. It's becoming more and more common practice." In defining the engineering occupation and its tasks, Amacher said the engineer "creates the circuit design and specifies the parts. Drafting and other functions can be done by a great number of other people .... if there is an engineers' shortage, there is one heck of a shortage of technicians." (Amacher, 1982)

Vince Amela, vice president of operations for Technical Sources, an employment agency for high-technology firms in Silicon Valley, described engineers as those who "crunch numbers, perform analysis and do feasibility studies. A technician, on the other hand, works with his hands." (Amela, 1982)

Pat Milne, director of job evaluation for Radford Associates, a management consulting firm for compensation administration in Silicon Valley, defined the engineer as "the designer of the computer, the one who also creates the test procedure. The technican constructs the prototype and does the final assembly. It's more physical work." (Milne, 1982)

Still others who work in the employment area of the high-technology industries describe the difference between technicians and

engineers in terms of federal tax exemptions. Clyde Albert, a personnel director at Lockheed, a firm with 20,000 employees in California, said technicians were:

> ... exempt salaried employees, paid on an hourly rather than salary base, while engineers have a college degree, although there are a certain number of engineers who don't have degrees and can get promoted and labeled one depending on job performance. (Albert, 1982)

According to many industry officials contacted, the percentage of engineers in any given company compared with the number of technicians seems to depend on the type of products the company is manufacturing. The semiconductor area, for example, has a small percentage of engineers compared with the number of technicians, while the software houses tend to have many more engineers than technicians. Bob Noyes, the vice chairman of Intel, estimated that of 10,000 employees at Intel, roughly 2,000 were trained engineers, while the rest worked in managerial, sales, and technician capacities.

Technician Supply and Demand

How ready is California to provide these workers? Most often, predictions and forecasts about the future possible shortfalls combine the needs for both engineers and technicians in high-technology industries, though they must be treated with separate consideraton. Included in the CEDD report last year were several statements of concern from among industry officials about the technician shortage:

> As Time magazine pointed out, the shortage of skilled craftsmen is a particularly serious problem. Most of our skilled workforce is reaching retirement age and there are insufficient numbers of new workers being trained to replace them. The need for machinists and tool and die makers, for example, already exceeds the available

> supply. There are two factors which have caused the shortage of craftsmen; first, blue-collar jobs are unattractive to young people who have gone increasingly into white-collar jobs; secondly, the training of skilled craftsmen is long and expensive. (CEDD, 1981)

These observations were again, more recently, reported by a Los Angeles Times article that said the Los Angeles association of tooling and machining companies estimated that up to 5,000 machinist jobs are unfilled.

The president of the 1,900-member Industry Education Council of California -- a statewide umbrella organization with representatives from business, government, and education -- recently expressed his concern about the shortage of technicians in a San Francisco Examiner and Chronicle article.

> While there is a shortage of engineers and other degree personnel, the bulk of the jobs in the future will be for support personnel who develop and build whatever the engineers and scientists conjure up, competent math and science-trained entry subtechnical and technical personnel. High school and junior college students are critical to our high-tech economy.

The American Electronics Association, in its report, "Technical Employment Projections: 1981-83-85," predicted that in California the percentage of technicians will grow by 113 percent; 108 percent for assemblers and production workers and 150 percent for drafters. (American Electronics Association, 1981)

Another way to gauge the possible status of technical jobs is to read the business section of the San Jose Mercury on any Monday. A recent edition (March 15, 1982) listed nearly ten pages of openings for people qualified to work either in technical or professional areas, mostly in high-technology industries.

Engineer Supply and Demand

There appears to be much more disagreement about the supply and demand for engineers than for technicians, in both California and the nation. The question of a shortage is hotly debated in engineering circles and both sides document their arguments with different sets of statistics. In the center of the debate are two professional engineering organizations, the Institute of Electrical and Electronics Engineers (IEEE) and the American Electronics Association (AEA). The IEEE, with 220,000 members, in a recent poll of 5,000 members, found that 81 percent do not believe there is an engineering shortage now and 70 percent doubt one will arise within a few years. The IEEE looks at the big picture -- the total supply of engineers in the entire country, of all ages, and questions whether a shortage really looms. (San Jose Mercury, February 1, 1982) The IEEE says that a dire need may exist in Silicon Valley for some specialties, such as microprocessor design engineers, but that the nationwide hiring rush of a year ago has tapered off amid the recession.

On the other side are the statistics put out by the AEA. From a survey of 671 electronics firms, the AEA predicts that, in 1985, U.S. companies will want to add 51,300 new computer and electrical engineers to their payrolls and that, in the Bay Area, 169 companies will need 2,500 engineers through 1985.

Industry observers of the debate often use the American Electronics Association comparison when describing the differences of the two organizations. The IEEE, they say, is dominated by management and academic people who want to keep the number of engineers low so that salaries will be higher. Critics of the AEA, on the other hand, say that organization is filled with big business interests who want to keep the number of engineering graduates high so that the salaries will be low. As Ned

Rasor, president of Rasor Associates, Inc., summed it up, "There will be serious problems if you stick by either of these exaggerated figures."

The IEEE is quick to point out flaws it sees in the AEA survey. "If you ask general managers what their projections are, they're always optimistic," says one engineer. And several firms may make projections on the basis of receiving government contracts while, of course, the contract can eventually go to only one firm. (San Jose Mercury, February 1, 1982)

The real cause for alarm, the AEA says, is the crunch at the colleges and universities. In their joint publication of October 1980, Science and Engineering Education for the 1980s and Beyond, the National Science Foundation and the Department of Education highlighted the nation's concern with the professional education of scientists, engineers, and technicians. These concerns were expressed as follows:

> The economic well being, security, and health and safety of Americans during the remaining two decades of this century, and beyond, will depend increasingly on our ability as a Nation to strengthen our technological and scientific enterprise. Several other countries are challenging our leadership in science and technology. During the coming decades, we are likely to be confronted with increasing competition, both from already industrialized countries and from those newly emerging industrialized countries with enormous labor resources. The United States cannot compete successfully in this environment unless it strengthens its technological base. This, in turn, will require that the Nation have sufficient numbers of engineers, scientists, and technicians with the skills and training required to meet present and future challenges, and that we make effective use of those skilled personnel. (National Science Foundation /Department of Education, 1980)

Among the ten principal findings of the report was the conclusion that there are at present, "shortages of trained computer professionals and

most types of engineers at all levels." Projections in the report indicated, however, that in 1990 the aggregate number of new science graduates at all degree levels:

> ...should exceed the number able to find jobs in the broad fields in which they are trained. With the possible exception of a few subfields, the numbers of new engineering baccalaureates should, by 1990, be adequate to satisfy projected demand for their services. (National Science Foundation/Department of Education, 1980)

Only two fields, as shown in Table II-1, computer sciences and statistics, may have large deficits of people. "In all engineering fields, projected baccalaureates, including those in engineering technology will exceed demand by almost 1.8 times the projected baseline openings," the report found. (National Science Foundation/Department of Education, 1980)

The report does not point toward a "crisis" status and at one point states:

> In general, the numbers of new science graduates should widely exceed the number who will be able to find jobs in the disciplines in which they are trained. ... These projections indicate that for engineers with bachelor's or master's degrees, the labor market in 1990 should be less tight than at any other time since the early 1970s as a result of faster expansion in the supply of qualified personnel than in a demand for their services. (National Science Foundation/Department of Education, 1980)

Taking into consideration the projections and evidence put forth by the professional electronics organizations and the federal education organizations, one can gain a more understandable picture of what is happening in California.

TABLE II-1

PROJECTED MARKET FOR SCIENTISTS AND ENGINEERS
IN 1990 BY FIELD AND LEVEL OF TRAINING
(all scenarios)

	Baccalaureates and Masters	Doctorates
Physical Sciences	Adequate	Adequate
Atmospheric	Balance	
Chemical	Adequate	
Geological	Adequate	
Physics and Astronomy	Adequate	
Engineering	Adequate	Uncertain
Aeronautical	Balance-Shortage	(Possible shortages some fields)
Chemical	Adequate	
Civil	Adequate	
Electrical	Adequate	
Industrial	Shortage	
Mechanical	Adequate	
Metallurgical	Adequate	
Mining	Adequate	
Petroleum	Balance	
Other	Adequate	
Mathematical Sciences	Adequate	Adequate
Mathematicians	Adequate	
Statisticians	Shortage	
Computer Professions	Shortage	Shortage
Life Sciences	Adequate	Adequate
Agricultural	Adequate	Adequate
Biological	Adequate	Adequate
Social Sciences	Adequate	Adequate
Psychologists	Adequate	
Other	Adequate	
All Fields	Adequate	Adequate

Source: Bureau of Labor Statistics, National Center for Education. As cited in National Science Foundation, 1980.

The number of Bachelor of Science degrees granted in engineering programs at the undergraduate level has been increasing slowly for the past ten years. As shown in Table II-2, there were 3,351 degrees granted to undergraduates in engineering in 1975-76 and 5,203 in 1979-80. In fact, so many students are flooding the engineering programs, not only in California but nationwide, that competition for admission to engineering programs at some University of California campuses was so great last year that students with a near-perfect 3.9 grade point average were being turned away. "We have a tremendous problem in redirection," said Karl Pister, Dean of the College of Engineering School at University of California, Berkeley.

> It's a big myth now. If a student wants to study engineering in the UC system, it's getting to be virtually impossible, especially in electrical and computer sciences. The cutoff point in those two fields is very high. We haven't lowered it but we can't raise it and there are a lot of students trying to get into those two areas in particular. (Pister, 1982)

TABLE II-2

CALIFORNIA INSTITUTIONS
BACHELOR'S DEGREES IN ENGINEERING PROGRAMS
1975-1980

	1975-76	1976-77	1977-78	1978-79	1979-80
UC:	1138	1208	1455	1711	1871
CSUC:	1473	1641	1860	2000	2187
Private & Other:	740	815	951	1042	1145
Total	3351	3664	4266	4753	5203

Source: Engineering Manpower Commission (EMC), 1979.

Pister said there were 2,217 students in 1980 who applied for admission to the college of engineering at Berkeley and only 765 were admitted. The remaining 1,347 were redirected. In 1981, 2,282 applied for admission and 858 were admitted. "There are an awful lot of qualified engineering students wandering the halls right now," Pister said.

On viewing the current employment situation, Dean Pister indicated that the employment rate at UC-Berkeley had not changed dramatically in recent years. "I don't see the supply exceeding the demand yet. Even in lean times, I believe there is always a shortage of good, qualified engineers and that there are always shortages in certain fields. Those are hard to anticipate."

However, Engineering Dean Jay Pinson, from California State University, San Jose, strongly believes that California is not producing nearly enough engineers.

> Lockheed alone would like to have all our graduates. It costs anywhere from $5,000 to $10,000 to bring in an engineer to work in California from another state and if we aren't producing enough engineers for our high-tech industries then I think we're doing a disservice to the society. I think it's dumb to sit around and talk about the surplus of engineers. (Pinson, 1982)

Pinson also bemoaned the difficulties of maintaining a quality education for the increasing numbers of engineering students who want to enter the field. "We have $20 million worth of equipment at San Jose and 80 percent of it is more than 20 years old. And I'd say we're better off than most other schools," he said. Equipment at universities are high in costs and other deans around the state also commented on the problems of trying to replace outdated instruments. A computer-aided design lab, consisting of a

computer and 20 terminals, for example, costs about $1 million. Computer time costs another $25 per hour per student. (Main, 1982)

Engineering Faculty Supply and Demand

What appears to be the crux of the problem in turning out engineers to meet the demands of the growing number of jobs both in California and the nation is the current and future serious shortage of engineering professors. While some undergraduate engineering programs have six or seven applicants for one space in the freshman class, there are diminishing numbers of students getting their Ph.D.s and remaining in the academic world to teach. According to a survey of unfilled faculty positions conducted by the National Society of Professional Engineers, in July 1980 there was a total nationwide shortage of 1,209 unfilled engineering faculty positions. The American Council on Education reported in the Fall of 1980 that ten percent of 16,200 engineering faculty positions in 244 engineering schools in the United States were vacant. In computer science, the discipline under the most pressure to produce graduates, the vacancy rate is highest. According to the Professional Engineering survey, institutions expect to have an average of 335 additional openings during the 1981-86 period because of retirements and 330 more because of expansion. (The Engineering Advisory Council, 1981)

The joint National Science Foundation Department of Education study, reported great concern for the shortage of students getting Ph.D.s and qualifying to teach the increasing numbers of engineering undergraduates:

> There is an immediate problem in providing for the acquisition, retention and maintenance of high-quality faculty to teach engineering and computer courses. This problem is the result of several

> factors, including rapidly increasing undergraduate enrollments, decreasing Ph.D. output, a widening gap between academic and non-academic salaries and the obsolescence of facilities and technical resources needed for research. (National Science Foundation/Department of Education, 1980)

California appears to be suffering from this dilemma as much or more than other states. A recent survey of the six deans of the engineering schools at the University of California, which supplies about ten percent of the nation's Ph.D.s in engineering, shows that at Berkeley there are 225 full-time permanent engineering professors, with 18 openings; Davis has 95 professors, with ten openings; Santa Barbara has 48 positions, with seven openings; Los Angeles has 135 professors, with three openings; Irvine has 26 positions, with four openings; and San Diego has 51 professors with five openings.

According to Bob Tyndall, vice chancellor for faculty and staff affairs at the California State Universities and Colleges, there are shortages of engineering faculty at all the schools. At the 13 colleges and universities in the system, there are 140 electrical engineering professors and there have been 14 "failed attempts" to locate replacements. There currently are 116 mechanical engineering professors, with 11 openings; 152 general engineering professors, with 12 openings; 169 civil engineers, with six openings; and 100 computer science professors, with 19 openings or unsuccessful searches. (Tyndall, 1982)

At California State University, San Jose, 38 of the 94 full-time faculty positions are open. For the past three years, the school has tried to hire for 38 faculty spots but could fill only six.

And the future question of who will teach the swelling number of engineering undergraduates in California cannot be described as optimistic when looking at the numbers of Ph.D.s granted since 1975-76. In that year, there were 528 doctorates granted by UC, private and other institutions in California, as shown in Table II-3. In 1976-77, the number decreased to 483, then to 479 in 1977-78. The number increased slightly to 501 in 1978-79 and to 502 in 1979-80.

TABLE II-3

CALIFORNIA INSTITUTIONS
DOCTOR'S DEGREES IN ENGINEERING PROGRAMS
1975-1980

	1975-76	1976-77	1977-78	1978-79	1979-80
UC:	311	258	257	267	277
Private & Other:	217	225	222	234	225
Total	528	483	479	501	502

Source: Engineering Manpower Commission (EMC), 1979.

It also should be mentioned that approximately halt of the engineering graduate students in this country are now foreign and that, since many of the junior faculty positions are filled with recent doctoral students, almost one-quarter of the young faculty in engineering now have bachelor degrees from foreign schools.

The reason for the engineering faculty shortage and dearth of Ph.D.s appears to be the gap between professors' and working engineers'

salaries. A student graduating with an electrical engineering degree, for example, is likely to make $6,000 more at his first job than his professor made in teaching him. (San Jose Mercury, February 1, 1982) As seen in Table II-4, the average salaries for an assistant professor on a 9- or 10-month contract in engineering and computer science is $21,634. A second-year programmer analyst can make $24,600, on the average. Likewise, an engineering or computer science full professor's average salary is $31,305, while a technical service manager in a large firm earns an average of $42,000.

James Methany, Dean of Engineering at California State University, said recently in Fortune Magazine, "I haven't even bothered to recruit an assistant professor since 1972. The most I can offer a new teacher is $19,000 and that would be insulting, demeaning." (Main, 1982)

As Henry Petroski, associate professor and director of graduate studies in civil and environmental engineering at Duke University wrote recently in the Washington Post:

> Now that America's engineering schools are overcrowded, understaffed, and poorly equipped, there seems to be an insatiable demand for their graduates. A bachelor's degree in engineering can command a starting salary in the high 20s, well beyond the salaries of young assistant professors who spent four or five years beyond their own bachelor's degree to earn an engineering doctorate. This kind of inequity has precipitated a series of problems that have impeded engineering education at a time when politicians and educators, corporations and foundations are expressing concern over America's ability to remain technologically fit in an increasingly competitive world. (Petroski, 1982)

TABLE II-4

MEDIAN SALARIES OF MANAGEMENT COMPUTER PROFESSIONALS BY POSITION AND SIZE OF COMPUTER SYSTEM, 1981

Management Position	Size of Computer System		
	Small	Medium	Large
Technical Services Managers	$32,900	$36,300	$42,000
Systems & Programming Managers	33,700	37,400	41,300
Operations Managers	24,700	29,100	38,100
Information Systems Directors	33,100	43,200	52,700

Source: Scientific Management Commission, 1981.

AVERAGE AND MEDIAN SALARIES FOR FACULTY MEMBERS ON 9-10 MONTH CONTRACTS BY FIELD AND RANK, 1980-81

Field	Professor		Associate Professor		Assistant Professor	
	Average	Median	Average	Median	Average	Median
Arts, Fine and Applied	$27,979	$27,255	$22,846	$22,263	$16,770	$16,404
Business and Economics	30,349	30,250	25,872	25,750	20,737	20,300
Engineering and Computer Science	31,305	31,609	24,769	25,125	21,634	21,500
Humanities, Language, Literature, Communications	29,108	28,000	21,112	21,900	17,724	17,520
Physical Education	27,566	26,251	22,196	21,565	18,291	18,750
Science and Mathematics	28,570	28,000	22,650	22,200	18,705	18,419
Social Sciences	29,606	28,562	22,434	22,253	18,140	18,000
Vocational Education, Home Economics, Nursing and Health			21,909	21,500	18,267	18,600

Sources: The Chronicle of Higher Education, November 3, 1980 and John Minter Associates, Faculty Salaries 1980-81 and Additional Earnings 1979-80.

If the engineering future looks grim at the college-level and beyond, informal surveys in California into science and math interests on the secondary level may give more cause for worry. A survey of the career plans of over 9,000 students in the ninth and eleventh grades in North County schools (Fremont, Palo Alto and Los Altos-Mountain View), published by Dr. Elizabeth Unseem in 1981, showed no significant interest in scientific or technical careers. Like students elsewhere in the country, the most popular career choices were performing artist, doctor, pilot, lawyer, and professional athlete. Electrical engineering ranked eleventh on the list and electronic technician placed fourty-second. (Unseem, 1981)

Figures from the National Center for Educational Statistics show that at the secondary level on the national scene, engineering now ranks second to business as the most popular choice of expected major field. Twenty-two percent of 1980 college-bound seniors chose business, while only ten percent chose engineering. Other top choices include health services, preprofessional fields, and social science, each with eight percent. In comparison, in 1972, engineering ranked sixth on the list, while business placed second. (National Center for Education Statistics)

III. K-12 SCIENCE AND MATH HIGH-TECHNOLOGY INDUSTRIES

Whether they go on to work in high-technology industries or are simply part of the general public that confronts new technologies in daily life and in the workplace, elementary and secondary school is important in preparing students for their futures.

Professional Workers

While the line distinguishing professional engineers from high-level technicians is blurred, it can be said that most of the engineers and computer scientists hired in high-technology industries need college degrees in engineering or computer science. Vince Amela of Technical Sources estimated that 75 percent of the workers who carry the title of "engineer" in the electronics field have college degrees in engineering.

A person's experience in kindergarten through twelfth grade plays an important role in his/her choice of and preparation for a professional career as an engineer or computer scientist. Interest in technical and scientific areas is sparked or extinguished in grades K-12, some career choices are made, and groundwork is laid in skills and substantive knowledge.

Choice of a Scientific or Engineering Career. Elementary and secondary school is the time when students make important choices about whether or not to enter scientific and engineering fields. Data from Project Talent, a longitudinal study conducted by the American Institutes for Research of the career development of 22,700 students who were in high school in 1960 and who responded to surveys in 1975, show that interest in a

science or engineering career[1] high school was closely related to being in a science or engineering area 12 years later. The study found:

> Whether or not a high school student planned to enter a science career had a zero-order correlation of .33 with being in a science occupation 12 years later for men, and a correlation of .23 for women. After partialing out 'Scientific Potential', the correlation was .21 for men and .20 for women. There are two important findings that follow from these data. First, the resulting partial correlations were very large relative to comparable partial correlations in this study, and for women there was only a small reduction of the correlation when controlling for 'Scientific Potential,' indicating that career plans did not merely reflect ability. Plans to work in a scientific field did influence a student's chances of achieving a science career independently of his or her abilities. (Gilmartin, et al., 1976)

In its 1977 survey, the National Assessment of Educational Progress (NAEP) asked 9-, 13- and 17-year-old students their favorite subjects and uncovered the following responses:

TABLE III-1

PERCENTAGES OF STUDENTS NAMING VARIOUS SUBJECTS IN SCHOOL AS THEIR MOST FAVORITE (AGES 9, 13, AND 17)

	Percent Naming Favorite Subject		
	Age 9	Age 13	Age 17
Science	6	11	12
Mathematics	48	30	18
English/Language Arts	24	15	16
Social Studies	3	13	13
Other	19	31	41

Source: National Assessment of Educational Progress, 1979.

Because the career decisions made in high school are important, the tendency of students to "turn off" to math as a subject and science as a career option as they progress through the grades is noteworthy.

The California Assessments Program in 1980-81 also showed declining enjoyment of math as students progress through their school years. Third- and sixth-graders in California were asked their opinions about math. The percentage of students who did not like math "at all" was nearly the same at grades three and six (ten percent at three and nine percent at six). However, the percentage of students at grade six who liked math "very much" was 45 percent, compared to 58 percent at grade three. (California State Department of Education, 1981)

While the NAEP survey showed that twice as many students called science their favorite subject at age 17 as compared to age nine, other questions asked in the NAEP survey showed declining interest in the pursuit of science as a career. About two-thirds of the nine-year-olds expressed favorable attitudes toward being a scientist; 64 percent said it would be fun and 69 percent said it would make them important. Two sets of questions asked of 13- and 17-year-olds revealed that interest in pursuing scientific careers diminished as the students grew older. On one set of questions, 52 percent of the 13-year-olds and 48 percent of the 17-year-olds appeared favorable to the idea of science as a career. On the other set, 51 percent of 13-year-olds and 44 percent of 17-year-olds expressed favorable opinions about working in science-related fields. (National Assessment of Educational Progress, 1979(b))

Ability to Pursue Professional Career and Success in Career

Enrollment and achievement in math and science courses in high school has been shown to be critical to the ability of a student to pursue a science or engineering major in college.

According to Joan R. Leitzel of Ohio State University in an article in The Chronicle of Higher Education, students who do not have early experience in science courses generally do not elect majors in science, and inadequate preparation in mathematics has prohibited large numbers of college and university students from entering strong science courses as freshmen. Leitzel cited a survey which showed that more than half the members of the freshmen class at Ohio State University whose math scores indicated that they were ready to take calculus majored in science or engineering, while only seven percent of those whose scores indicated they had little or no skills in algebra did so. (Trotter, 1982)

In High School and Beyond, a national longitudinal study by the National Center for Education Statistics, a survey conducted in Spring 1980 of students leaving high school found that students with more mathematics and science coursework were more likely to say they would choose science and other quantitative fields in college. Students enrolled in academic programs in high school more often expected to choose engineering and preprofessional fields, while vocational program students were more likely to choose business and other vocational fields. As might be expected, students in academic programs generally had taken more years of coursework in math and science than students in vocational or general programs. Fifty-five percent of students in academic programs took three or more years of math, as compared to 22 percent of the students in general programs and 18 percent of the students enrolled in vocational curricula. Forty-one percent of academic students took three or more years of science, as compared to 13 percent of the students in general curricula and nine percent of the students in vocational programs. (National Center for Education Statistics)

Other evidence that high school preparation may be important to the selection of scientific careers is that college-bound seniors planning

to study physical sciences and math in college have higher average SAT scores than those planning to major in other fields. Scores on the math portion of the SAT have been linked with years of study of mathematics. See Table III-2. It must be recognized that students who choose scientific careers are self-selected as a bright group, and that innate abilities, environmental, and other factors play important roles in achievement on the SAT and in career decisions.

TABLE III-2

MATH SAT SCORES AND NUMBER OF YEARS OF MATH STUDY

1973-74		1974-75		1975-76		1976-77	
Years of study	SAT-M mean scores	Years of study	SAT-M mean scores	Years of study	SAT-M mean scores	Years of study	SAT-M mean scores
1	362	1	361	1	355	1	354
2	402	2	394	2	393	2	387
3	458	3	451	3	450	3	445
4	525	4	516	4	519	4	516
4+	599	4+	587	4+	593	4+	582

Source: College Board Memorandum.

Data from Project Talent, analyzed by researchers from the American Institutes for Research, supply the most complete information available on the relationship between enrollment and achievement in high school math and science, selection of a science or engineering career, and success in that career.

The reseachers posited that three things occur in high school that are critical to a student becoming a scientist or engineer. They include preparing for college, acquiring mathematics and science knowledge, and developing the expectation of becoming a scientist.

"Scientific Potential," an index composed of 32 ability tests, was correlated with males who had science career plans in eleventh grade and held a job in a science field 11 years after high school graduation and those who did not. The results indicated that "Scientific Potential" predicted whether or not a student would hold a scientific job in the future. The largest determinant of whether a student achieved his plan was high school math ability. How well and widely the student read and his visual imagery skills were also found to be related to the probability of establishing a science career by age 29.

The number of semesters of science, foreign language and math courses taken were all strongly and positively related to science career plans, as were the number of additional science courses planned in high school. Grades in all types of courses, science and non-science, showed strong relations to career plans.

The "Scientific Potential Index" was also found to predict four measures of success within scientific careers. The measures that were correlated with the index included: 1) inclusion of the respondent in American Men and Women of Science; 2) the number of references to the respondent's publications in the Science Citation Index or the Social Science Citation Index; 3) prestige of undergraduate institution; and 4) prestige of the graduate institution attended by the student. The researchers concluded:

> While the magnitude of the correlations indicates that high school abilities as measured by Scientific Potential play only a moderate role in determining success among those who enter science careers, nevertheless this level of prediction is surprisingly high. A number of later factors, most notably those related to undergraduate and graduate education, should be expected to play a much larger role in determining a student's level of success as a scientist. Furthermore, the criteria used were rather crude, and the samples

> used had a very restricted range on the Scientific Potential index. All in all, these data indicate that the Scientific Potential index is a reasonable predictor of success as a scientist as well as of entry into a science career. (Gilmartin, et al., 1976)

Other reseachers at the American Institutes for Research used Project Talent data to show that high school mathematics achievement is critical to the development of a range of professional careers. High school students planning careers that require math (e.g., engineers and physical scientists) were shown to have average math achievement scores at the seventy-fifth percentile, but those who persisted and had entered a math-related career by age 29 had math achievement scores averaging in the ninetieth percentile in twelfth grade. The study also showed that fewer than three percent of high school students not planning careers that require college mathematics switched into these careers at a later date. (Wise, Steel and MacDonald, 1979)

Math Skills Needed for College. The Academic Senates of the University of California, the California State University and the California Community Colleges recently endorsed a statement on the competencies in English and mathematics expected of entering freshmen. The statement for mathematics read:

> The amount of recommended high school preparation in mathematics for college-bound students depends on the major field of study to be pursued in college, regardless of any specific college or university admission requirement in mathematics. Students who plan to major in the natural and life sciences, engineering, premedicine, other science-related fields, and business and economics should prepare for the college-level calculus requirement in these majors by taking four years of mathematics in high school and additional mathematics courses if available. Many majors in the social sciences or other professional and pre-professional fields require baccalaureate-level statistics or calculus, sometimes both. Three

> years of high school mathematics are required as preparation for statistics. To enable students to have full access to college and university programs and career opportunities, it is recommended that all college-bound students master the skills and techniques of high school mathematics through intermediate algebra. This means that all prospective college students should take as a minimum full-year courses in basic algebra, geometry, and intermediate algebra. (Academic Senates of the University of California, California State University, and California Community Colleges, 1982)

Nonprofessional Workers

Workers in jobs in high-technology industries that do not require a college degreeneed varied amounts of math and science education, depending upon their specific tasks. Job types range from factory work, like assembly of microcomputer chips, to repair of sophisticated electronics machinery, to drafting. Limited information exists on which math and science courses are needed for preparation for these jobs, because there is such a wide range of jobs, high-technology jobs are changing so rapidly, and employers usually hire on the basis of work experience, specific job skills, and/or a degree from a community college or vocational institute. A study that included in-depth interviews with numerous personnel officers and vocational education experts would be helpful in answering this important question in detail.

According to Ralph Baker, vice president of Dyna-Kor Micrographics in Oakland, and a former high school principal, the lower-level jobs in high-technology industries require little specific knowledge of math or science. For example, persons accepted to Dyna-Kor's training program in micrographics, which trains microfilm technicians, need only tenth-grade math and reading skills as measured by standard achievement tests. Assemblers of electronic circuits may need a high school education, but need no specific science or math skills. Data processing employees, who turn

computer output into microfiche, need to know high school algebra and would find basic computer programming helpful, according to Baker.

Most nonprofessional jobs with higher skill levels, such as electronics repair, require a vocational education or community college degree. To pursue a field like electronics at the community college or vocational education level, Baker said, a student needs a good background in high school algebra and geometry. Baker also stated that high school courses in physical sciences, especially physics and chemistry, are helpful for nonprofessional high-technology jobs that demand higher skill levels. While Baker said that high school students planning to enter nonprofessional jobs do not necessarily need the same level or type of science courses as do their college-bound classmates, knowledge of the practical aspects of physical science is important.

Vince Amela of Technical Sources echoed Baker's opinion. He said that his experience with placing people in technician jobs within the electronics industry revealed that most employers look for a degree from a community college, along with one or two years of industrial experience. High school math and science, Amela said, are important in providing a good foundation for community college coursework. Amela stressed that physics and math are the courses important for persons considering jobs in the electronics industry.

Baker said that if high schools offered more technical curricula, the need for many students to attend vocational or community college programs before entering high-technology jobs might be eliminated. "The types of skills many of these workers will need," Baker said, "are similar to but much more basic than those needed by engineers -- knowledge of calibration, for example."

Academic research shows that students who have good skills in math when they enter a vocational education program are more likely to finish the program than students who enter such programs without adequate skills.Brantner and Enderlein studied variables related to the prediction of potential dropouts in vocational programs and found a significant difference on General Aptitude Tests Battery numerical scores between students who finish their vocational programs and those who drop out. (Brantner and Enderlein, 1973)

A review of vocational education and mathematics by researchers at the National Center for Research in Vocational Education at Ohio State University led to a similar conclusion:

> ... mastery of basic mathematics skills, at the minimum, is required for optimum success in vocational study and a person's vocational development, in the long run, is inhibited by deficiencies in fundamental academic skills, including mathematics skills. (Long, 1980)

General Public

Even people who are not directly employed in high-technology industries are likely to find that the technological revolution demands that they be comfortable with technological subjects. In addition to pervading everyday life, new technologies will affect a great number of jobs even outside the high-technology industries. If Porat's estimate that 50 percent of the labor force in 1995 will be involved in information-related jobs is correct, the job skills required for the future will be profoundly different from those needed today.

Dr. Stanley Pogrow, Associate Professor of Educational Administration at the University of Arizona, illustrated how traditional work is likely to become more technical. He said:

> The next generation of word processors will automatically check spelling and some aspects of punctuation. By that time, large numbers of information workers will find it advantageous to use the capabilities of the word processor to compose and edit the original versions of their work by themselves. At that point, the clerical workforce will have to take on additional, or different, functions.... Such functions will likely involve forms of non-routine interactions with data bases which will require engaging in linear logic technical operations. (Pogrow, 1982)

Pogrow also reported that, according to a study by Arthur Luehrmann of the Lawrence Hall of Science, 80 percent of new jobs at Pacific Gas and Electric Company require computer literacy. As another illustration of how technological literacy is becoming more important in the workplace, Pogrow cited a 1981 report by Hymowitz that said that GM, which now employs one skilled worker for every 5.6 assembly-line workers, may need a one-to-one ratio by the year 2000. Pogrow concluded:

> Such employment trends suggest that education is going to be even more of a prerequisite for employment in the future, and that a significant portion of the workforce is going to have to acquire new work skills and habits in the near future. Much of these new skills will relate to using technology, and a large percentage of the growing non-manufacturing workers are going to have to begin to perform increasingly sophisticated technical operations. (Pogrow, 1982)

Pat Hill Hubbard of the American Electronics Association told the Senate Select Committee on Small Business in February 1981 what changing skill needs mean for high school preparation:

> The increasing technological complexity of the workplace is creating a need for high school preparation in physics and chemistry -- both of which first require competency in algebra -- even for those not going on to college. (Hubbard, 1981)

Ronald E. Anderson and Daniel L. Klassen, writing for the Minnesota Educational Computing Consortium, discussed the need for computer literacy in the modern technological world. They said:

> For the individual, an understanding of computer technology and uses is important because it reduces bewilderment about computers and promotes a balanced view of the computer's role in society. Such understanding also enables people to use and influence the design of computer based social services and to develop informed opinions regarding particular computer applications having political, economic and social implications. (Anderson and Klassen, 1981)

Anderson and Klassen concluded that understanding of computers is currently inadequate.

> Public understanding of computers and their applications has not kept pace with their availability and use. The AFIPS/TIME survey in 1971 showed that public attitudes are often unrealistic and negative, and understanding of computers is sometimes incorrect. The young, who have grown up in the computer age, are not much better informed. The recently conducted Minnesota computer literacy study found that most junior and senior high students know very little about computers and their implications for society. Furthermore, most students do not understand the limitations of computers. More than half of the 1,500 students believed that 'computers help people make decisions by providing correct answers to any question.' (Anderson and Klassen, 1981)

In addition to technological literacy being important to people's ability to cope with an increasingly technologically complex society, it appears that an understanding of science and technology is also important to public support for scientific research and development.

Hubbard told the Senate Select Committee on Small Business that education in technology is important for this reason. She said:

> Unlike the U.S., other countries are acting on the recognized need for all citizens to have a technological educational foundation, so that those who do not actually follow science and engineering careers will, nevertheless, make informed supportive decisions in support of high technology. (Hubbard, 1981)

The link between science education and support for scientific research and development was established by a survey conducted by the NAEP, in 1978. A group of 9-, 13- and 17-year-olds were tested during 1976-77 for their knowledge of biological, physical, and earth sciences, "integrated topics", scientific processes, and the relationships between science and society. The study also evaluated levels of support for basic and applied scientific research. The study found a positive correlation between performance in the cognitive measures and support for research. Analysis by NAEP showed that the difference in support for both basic and applied research was greatest between those scoring in the lowest and the highest quartile groups on the cognitive tests. (Noe, 1978)

Footnote

[1]Both researchers and practitioners were labeled as scientists in the study. Among the professional careers examined in the study that are relevant to high-technology industries are various fields of engineering: electrical, mechanical, aeronautical, chemical and industrial.

IV. STUDENT ACHIEVEMENT IN MATH AND SCIENCE: THE EVIDENCE

Are today's students preparing adequately to cope with and work in an ever more technological world? Student achievement in math and science is one gauge for determining if students have adequate high school backgrounds. There has been substantial press coverage of the decline in student achievement in recent years. Does the evidence support such claims?

Test Scores

Test scores are often used as an indicator of student achievement, and as a way of comparing the performance of California students with students nationwide. A problem with using scores on standardized tests to evaluate the preparation of students for high-technology jobs was voiced by David Gordon, Assistant Chief of Program Evaluation at the California Department of Education. Gordon said that most standardized tests evaluate either aptitude or the attainment of basic functional skills. They do not, he said, measure the attainment of the higher level substantive knowledge or skills needed by students who intend to pursue professional careers in high-technology areas. Nor, he said, do the tests measure the ability of students who do not intend to enter professional careers in high technology to function in a technologically complex society. (Gordon, 1982) Another caveat to keep in mind when reviewing test scores is that scores cannot be the sole measure of evaluating students. Numerous critics of standardized examinations have alleged, with extensive evidence, that such tests measure exposure to upper-middle-class culture rather than ability or intelligence. Even the Educational Testing Service, which developed the Scholastic Aptitude Test (SAT), has said that test scores should not be used as the sole evaluation mechanism of individuals.

California Assessment Program (CAP). The California Department of Education has, since 1969, conducted an annual assessment of the reading, language, and math skills of the state's third, sixth and twelfth graders. From 1969 to 1974, the CAP tests revealed declining achievement in all three areas for sixth and twelfth graders, while the scores in reading for third graders (the only area measured until 1979) rose slowly but continuously. Since 1974, the scores of sixth graders have risen slowly in all three areas. The math scores of twelfth graders have been improving since 1976 and, in 1980, scores in all the areas tested improved for the first time. (California State Department of Education, 1981)

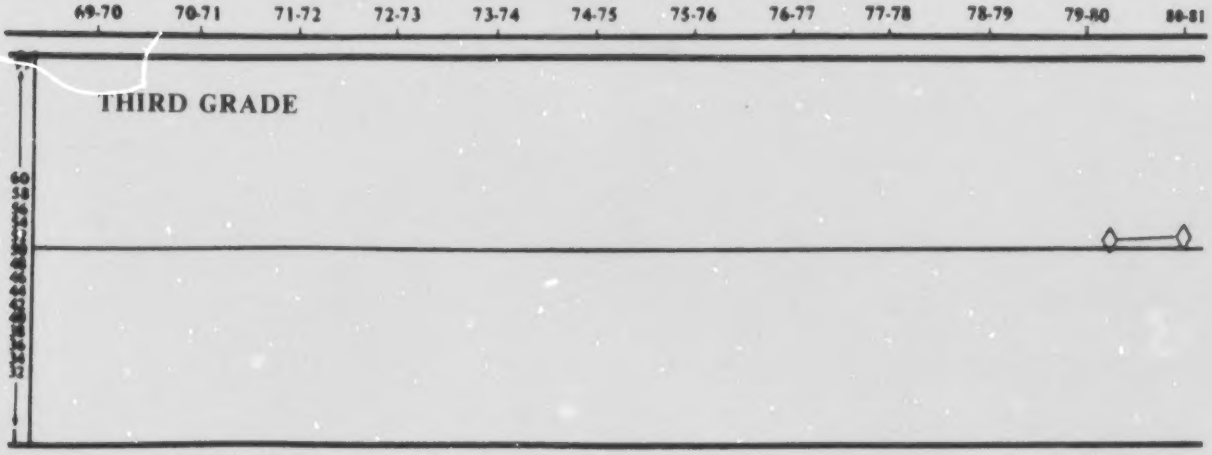
Figure IV-1 shows the historical change in the performance of California's third, sixth, and twelfth graders on the mathematics exams when compared to the nation as a whole.

Percentile rankings that compare the performance of California students on the CAP tests to national norms were developed through special equating studies. These data are of limited usefulness because the national norms are dated and the performance of California students today therefore is being compared with what the publishers of standardized tests estimate student performance nationwide would have been had all U.S. students taken the test the year the norm was developed. These data indicate that California students in 1980-81 performed above the national median in third and sixth grade but dropped to below the national median in the twelfth grade. Specifically:

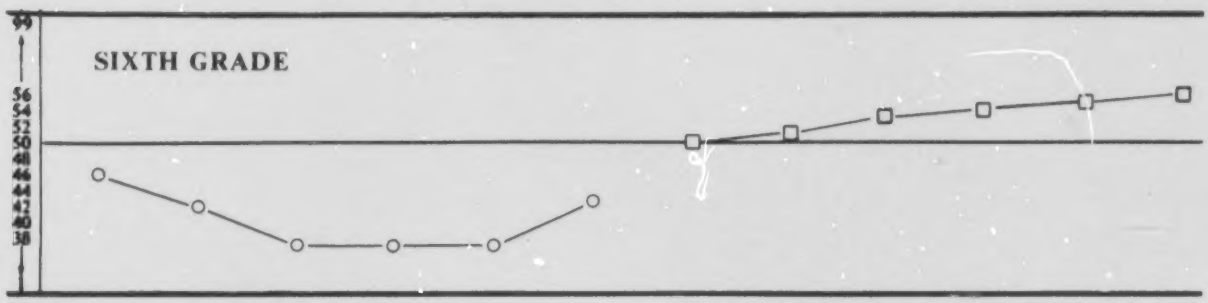
- The median third-grade California student scored higher than 59 percent of the national sample in reading, 54 percent in written language, and 52 percent in math on the basis of 1973 norms.

FIGURE IV-1

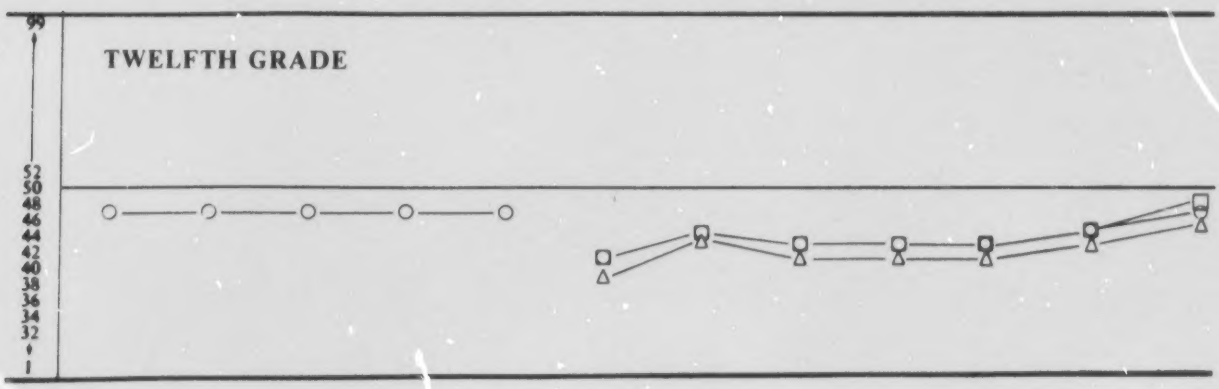
NATIONAL PERCENTILE RANKS OF MEDIAN CALIFORNIA STUDENT PERFORMANCE ON MATH EXAMINATIONS



Key: ◊ *Survey of Basic Skills: Grade 3*–equated to CTBS (1973 norms)



Key:
○ *Comprehensive Tests of Basic Skills* (1968 norms)
□ *Comprehensive Tests of Basic Skills* (1973 norms)



Key:
○ *Iowa Tests of Educational Development* (1962 norms)
□ *Sequential Tests of Educational Progress, Series II* (1970 norms)
△ *Tests of Academic Progress* (1970 norms)

Source: California State Department of Education, 1981

- The median sixth-grade student in California scored above 57 percent of students nationwide in reading, 55 percent in written expression and 56 percent in math, on the basis of 1973 national norms.

- The median twelfth-grade California student scored, on the basis of three different 1978 norms, in the 44th, 42nd, and 47th percentiles in reading, the 43rd, 40th, and 57th percentiles in language, and the 46th, 41st, and 55th percentiles in mathematics. (California State Department of Education, 1981)

High School and Beyond Study. While twelfth-grade California students compared rather poorly with students nationwide on the basis of most of the equating studies, they performed slightly above the national averages in tests of high school seniors administered as part of the National Center for Education Statistics' national longitudinal study, High School and Beyond. See Table IV-1. (California State Department of Education, 1981)

TABLE IV-1

READING AND MATH TEST SCORES OF 1980 SENIORS FROM HIGH SCHOOL AND BEYOND STUDY

Test score	National	California
Reading (Mean)	49.64	49.85
(Median)	49.95	49.98
Math – Part I (Mean)	49.60	50.48
(Median)	49.39	50.66
Math – Part II (Mean)	49.67	50.14
(Median)	48.06	51.31

Source: California Department of Education, 1981

National Science Foundation Report. The widely quoted study by the National Science Foundation and the Department of Education, Science and Engineering Education for the 1980s and Beyond, documented the decline in all tested areas of the scores of elementary and secondary school students nationwide since the mid-1960s. Among the studies cited in the report is one by Harnischfeger and Wiley, who reviewed data of commonly used achievement tests. Harnischfeger and Wiley concluded that, since the 1960s, achievement test scores have declined in all tested areas for grades five through 12, with the most dramatic drops occurring in recent years and being most evident for higher grades. Their research determined that the test score decline was not a result of differences in test content or scale from year to year. (National Science Foundation/Department of Education, 1980)

National Assessment of Educational Progress Evaluation. The National Assessment of Educational Progress (NAEP), conducted by the Education Commission of the States, confirmed statements by the NSF authors. The first national assessment of mathematics was completed in 1973, and a number of items were surveyed again in 1978 to assess change in achievement. Findings show that achievement levels in all three age groups tested declined over the five-year period. The decline was more pronounced for older students. On average, 17-year-olds performed four percentage points lower than did 17-year-olds five years earlier, 13-year-olds performed two percentage points lower, and 9-year-olds performed one percentage point lower. The assessment revealed that students at all levels could perform rudimentary arithmetic as well as they could five years earlier, but that they experienced a decline in their ability to interpret and understand problems. (National Assessment of Educational Progress, brochure) See Table IV-2.

TABLE IV-2

CHANGES IN MATHEMATICAL ACHIEVEMENT, 1973-78, FOR 9, 13, AND 17 YEAR-OLDS: NATIONAL ASSESSMENT OF EDUCATIONAL PROGRESS

	Mean Percent Correct		Change in Mean Percent Correct
	1973	1978	
9 Year-Olds			
All items	38%	37%	-1
Mathematics Knowledge	55	55	-1**
Mathematics Skills	26	26	0
13 Year-Olds			
All items	53	51	-2*
Mathematics Knowledge	64	64	0
Mathematics Skills	51	49	-2*
Mathematics Understanding	52	50	-2
17 Year-Olds			
All items	52	48	-4*
Mathematics Knowledge	63	63	0
Mathematics Skills	55	50	-5*
Mathematics Understanding	62	58	-4*

*Change is significant at the .05 level.
**Figures do not total because of rounding.
Source: National Assessment of Educational Progress, Changes in Mathematical Achievement, 1979.

Assessments of science achievement in 1970, 1973, and 1977 showed a marked decline in all three age groups between 1970 and 1973. This downward trend lessened for 9- and 13-year-olds between 1973 and 1977, with continuing declines in achievement in physical science being accompanied by some stability in achievement in biology. The achievement levels of 17-year-olds continued to decline. See Figures IV 2-4. (National Assessment of Educational Progress)

Changes in Science Achievement From 1969-70 to 1972-73 and From 1972-73 to 1976-77 for 9-, 13- and 17-Year-Olds

FIGURE IV-2

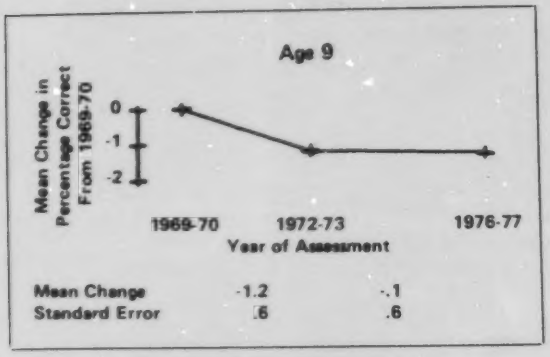


FIGURE IV-3

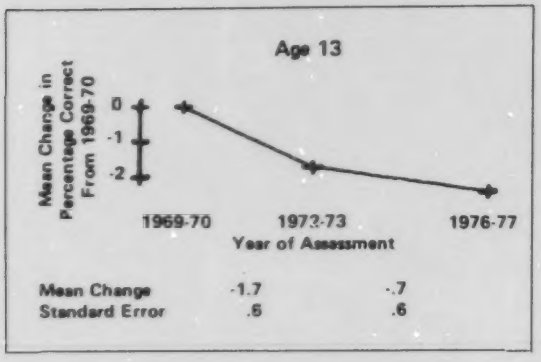
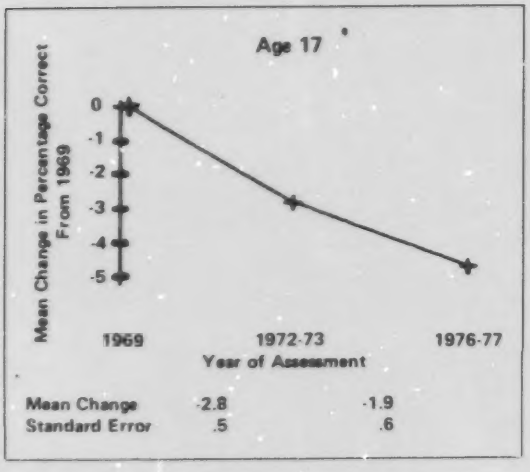


FIGURE IV-4



The decline in science and math scores appears to be slightly greater than declines in social studies scores and considerably more pronounced than the decline in reading or writing scores on NAEP examinations. (Jones, 1981)

General SAT. Unlike the CAP and the NAEP evaluations, SATs reflect the aptitude of only those students who are college-bound, since the purpose of the test is for making college admissions decisions.

Examination of SAT scores of California students from 1972 to the present reveals a significant decline until the late 1970s. Both verbal and math scores have improved some years since the late 1970s, but the mean verbal scores of California students in 1981 remained 38 points below the 1972 level, and the mean math score remained 18 points below the 1972 level. See Table IV-3.

TABLE IV-3

MEAN SAT SCORES: CALIFORNIA

	SAT - Verbal			SAT - Mathematics		
	California	Year to Year Difference: California	UC Entering Freshmen	California	Year to Year Difference: California	UC Entering Freshmen
1960	---		535	---		552
.			.			.
.			.			.
.			.			.
.			.			.
1968	---		561	---		593
1969	---		*	---		*
1970	---		553	---		585
1971	---		544	---		583
1972	464		543	493		581
1973	452	-12	533	485	-8	575
1974	450	-2	525	484	-1	572
1975	435	-15	510	473	-11	564
1976	430	-5	507	470	-3	562
1977	427	-3	504	470		564
1978	427		505	466	-4	564
1979	428	+1	500	473	+7	563
1980	424	-4	---	472	-1	---
1981	426	+2	---	475	+3	---

* These data are not reliable.

Note: The percentage of UC entering freshmen taking these exams has been quite consistent over time, on the average, 88%, with a standard deviation of 1.5.

Sources: College Board, Admissions Testing Program Reports, College-Bound Seniors, 1972-1980; University of California, Preliminary Report: Concerning College Entrance Examination Board Scholastic Aptitude Test Scores, Fall 1960; and University of California, Frequency Distribution of College Board Examinations, 1968-79. National data for 1968-1971 are estimates made for College Entrance Examination Board, On Further Examination: Report of the Advisory Panel on the Scholastic Aptitude Test Score Decline, Willard Wirtz, Chairman (New York: College Board, 1977). As cited in University of California, 1981.

A report to the Policy Committee on the University of California's Activities to Assist Underprepared Students expressed special concern for the declining SAT scores of freshmen entering the nine-campus University of California system. It said:

> We are convinced, by test score trends, basic skills course enrollment trends, and anecdotal evidence, that a decline in the skill level of UC's entering freshmen has occurred. In fact, although, on the average, UC freshmen still score well above the national means on the College Board's SAT exams, those mean scores have been declining faster than the national means for all college-bound seniors in California. In 1968, not one campus of the university had as many as half its entering students scoring below 550 on the SAT-Verbal exam; in 1979, more than half of the entering students scored below 550 on all eight UC general campuses, and on five of our campuses (Davis, Irvine, Los Angeles, Riverside, and Santa Barbara) at least two-thirds of the students scored below 550. In 1979, every campus except Berkeley had fewer entering students scoring above 550 on the SAT Verbal exam than it had in 1968, despite an increase of 4,500 students taking the test. In mathematics, the number scoring below 550 had increased but not as dramatically as in the verbal scores. (University of California, 1981)

Nationwide, the mean SAT scores for both verbal and math have declined since 1968 and, as of 1981, the mean verbal score was 42 points below its 1968 level and the mean math score was 26 points below its 1968 level. See Table IV-4. (University of California, 1981)

When the SAT scores of California students are compared with the scores of students nationwide, it is evident that both the math and science test scores of California students exceeded those of students nationwide in the early 1970s, dropped more rapidly than scores nationwide in the middle-1970s until they were actually below the national mean in 1978 and, in the past few years, have risen, with the result that they now exceed the national mean. See Figure IV-5.

TABLE IV-4

MEAN SAT SCORES: NATIONAL

	SAT - Verbal		SAT - Mathematics	
	National	Year to Year Difference	National	Year to Year Difference
1960	---		---	
.				
.				
.				
.				
1968	466		492	
1969	463	-3	493	+1
1970	460	-3	488	-5
1971	455	-5	488	0
1972	453	-2	484	-4
1973	445	-8	481	-3
1974	444	-1	480	-1
1975	434	-10	472	-8
1976	431	-3	472	0
1977	429	-2	470	-2
1978	429	0	468	-2
1979	427	-2	467	-1
1980	424	-3	466	-1
1981	424	0	466	0

* These data are not reliable.

Note: The percentage of UC entering freshmen taking these exams has been quite consistent over time, on the average, 88 percent, with a standard deviation of 1.5.

Sources: College Board, Admissions Testing Program Reports, College-Bound Seniors, 1972-1980; University of California, Preliminary Report Concerning College Entrance Examination Board Scholastic Aptitude Test Scores, Fall 1960; and University of California, Frequency Distribution of College Board Examinations, 1968-79. National data for 1968-1971 are estimates made for College Entrance Examination Board, On Further Examination: Report of the Advisory Panel on the Scholastic Aptitude Test Score Decline, Willard Wirtz, Chairman (New York: College Board, 1977). As cited in University of California, 1981.

Care must be taken in interpreting these data, since the percentage of students who take the SAT varies greatly from state to state. The percentage of students taking the test ranges from two percent in Mississippi to 69 percent in Connecticut. Thirty-five percent of California students take the SAT whereas, in 28 states, less than 20 percent of seniors take the test. (San Francisco Chronicle, November 2, 1981) The top students in any state take the SAT, giving an advantage in terms of mean scores to states in which a small percentage of students take the test.

FIGURE IV-5

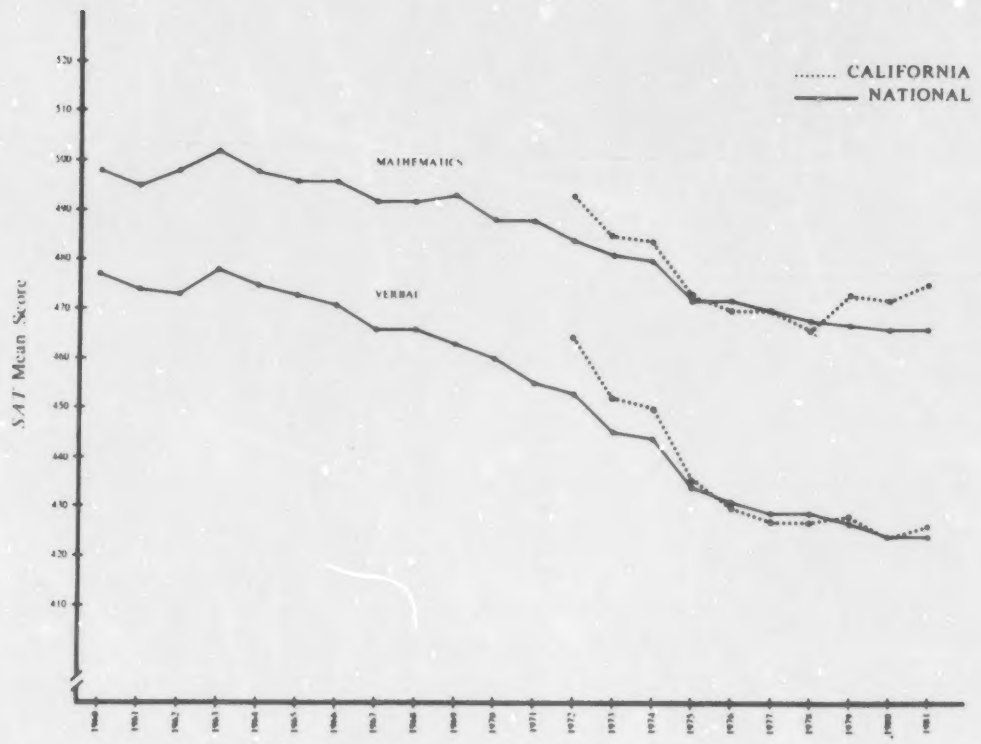


Fig. 26 . *Scholastic Aptitude Test (SAT)* scores for high school seniors in California and the United States, 1960 through 1981

SAT Achievement Tests. Some college-bound students take achievement tests in specific subject areas, in addition to the general SAT. Mean scores on the achievement tests have declined substantially for both California and UC students since accurate records of the scores were first maintained. California students dropped 22 points on the English composition test and 31 points on the mathematics (level 1) test since 1972, while UC entering freshmen declined 51 points between 1968 and 1979 on the English composition test and 56 points on the mathematics (level 1) test. The percentage of UC students taking these exams was fairly consistent until 1979, when the University began requiring virtually all students to take the mathematics exam. (University of California, 1981)

In contrast with California, the scores of students nationwide taking the achievement tests have remained more stable. The mean score on the English Composition test has actually risen two points since 1972, and the mean score on the mathematics (level 1) test has declined by five points. Again, it must be taken into account in analyzing these figures that a much larger proportion of entering UC students take the exams than do students nationwide. (University of California, 1981)

Nationwide, the scores of students on the four science and math achievement tests were fairly steady until about 1978, when the average scores in physics and mathematics dropped significantly. The general (math and verbal) SAT scores of students taking the achievement tests have remained steady, while the scores of those not taking the achievement tests have fallen, as described earlier. These data could indicate a widening gap in basic understanding of science between professional scientists and engineers and the general public, because students planning to major in science and math fields generally take the science and math achievement tests.

NAEP Assessments of Young Adults. In 1973 and 1977, the NAEP conducted evaluations of the level of scientific knowledge among young adults aged 25-36. The 1977 evaluation revealed a decline in performance from 1973 levels. In 1973, 44.6 percent responded correctly to 20 exercises, while in 1976-77 only 40.7 percent responded correctly. The decline was statistically significant among young adults in the Western region, while it was not statistically significant in the Northeastern and Central region and the young adults in the Southeast held their own. (Holmes and Wright, 1980)

Conclusion: Reasons for Test Score Declines

Many explanations have been advanced for the declines in test scores. The Advisory Panel on SAT Score Decline reported to the NSF that between two-thirds and three-fourths of the decline in SAT scores between 1963 and 1970 can be accounted for by compositional changes in the SAT-taking group (e.g., larger numbers of seniors taking the SAT). This factor, however, was determined to have played an insignificant role after 1970. (National Science Foundation/Department of Education, 1980)

Possible reasons for the decline after 1970 include: deficiencies in the availability and training of teachers and the availability and quality of materials; decrease in student motivation; grade inflation; lowered graduation and college entrance standards; reduction in the number of required courses; and the impact of television. Also identified as a possible culprit has been the return to "basics" which has been accompanied by what the National Research Council calls "molecularization" of the curriculum into disembodied learning objectives, the achievement of which is usually indicated by student performance on standardized multiple-choice tests that emphasize the most superficial aspects of learning. (National Research Council, 1979)

Remedial Coursework in High School and College

The percentage of students taking remedial coursework is another way of evaluating student achievement.

The High School and Beyond study found that, at the high school level, 27 percent of California students were taking basic (including remedial) mathematics in 1979-80, compared with 31 percent of students nationwide. These numbers must be interpreted with caution, because of the difficulty in assessing the level of the course by its title. (California State Department of Education, 1981)

Nationwide, the number of students taking precalculus in mathematics in college is increasing. A study by the Conference Board of the Mathematics Sciences revealed that enrollments in courses below calculus in four-year colleges and universities increased by ten percent between 1970 and 1975, while the number of first-time students in these institutions increased by only 2.7 percent. In two-year colleges, high school level mathematics courses accounted for 36 percent of all math enrollments in these institutions, compared with 26 percent in 1966 and 29 percent in 1970. (Conference Board of the Mathematics Sciences, 1980-81)

The University of California has experienced an increase in students enrolling in precalculus courses. Commenting on the decline in student preparation, a report to the Policy Committee to Assist Underprepared Students stated:

> This decline is borne out by increasing enrollments in Subject A or equivalent writing courses and in precalculus math courses. Between 1975-76 and 1979-80, we estimate that the percent of UC entering freshmen taking pre-Subject A and Subject A or equivalent writing courses rose from 49 percent to 56 percent. Enrollments in precalculus math classes rose from 36 percent to 49 percent. And this decline was also reported to us

> anecdotally by many of the faculty and administrators we interviewed. (University of California, 1981)

According to Joan R. Leitzel, an Associate Professor of Mathematics at Ohio State University quoted in Education Week, enrollment in remedial math effectively rules out selecting science and math majors because the student often cannot take college-level courses until he/she is a sophomore. Leitzel was expressing her concern in light of a 72-percent increase in Ohio State University students taking remedial math courses between 1974 and 1980. (Walton, 1982)

V. FACTORS IN STUDENT ACHIEVEMENT

Several factors determine if students graduating from high school will be well prepared for living and working in an increasingly technologically complex society. These factors include the time spent by students in relevant coursework, the qualifications and availability of teachers to stimulate and guide student interest and learning, and the availability of materials and courses that are relevant to attaining needed skills.

Participation in Science and Math Course

Background. In Section III, the relationship between scores on the math portion of the SAT, the number of math courses taken, and career plans were mentioned. Other studies also link the scores on achievement tests with courses taken. Project Talent showed that the strongest predictors of twelfth grade math achievement were ninth-grade math achievement and the amount of math taken in high school. (Wise, Steel, and MacDonald, 1979)

Table V-1 shows how, on the CAP tests, twelfth-grade students who had taken only general math achieved a 50 percent correct score, while students who had taken Algebra I and II and Geometry obtained a correct score of 86 percent. (California State Department of Education, 1978)

The Beginning Teacher Evaluation Study (BTES), a study of teachers who had several years of experience, focused on instruction in reading and math at grades two and five. This six-year study (1972-1978), funded by the National Institute of Education through the California Commission for

TABLE V-1

PERCENT OF TWELFTH GRADE STUDENTS AND THEIR PERCENT CORRECT SCORES BY MATHEMATICS COURSES TAKEN

Mathematics courses taken	Percentage of students			Percent correct score		
	Boys	Girls	Total	Boys	Girls	Total
General Math only	23.1	25.5	24.3	51.6	48.6	50.0
Algebra I only	2.4	2.3	2.3	62.2	59.5	60.9
General Math + Algebra I	20.0	23.4	21.8	62.1	59.0	60.4
Algebra I + Geometry	2.2	2.5	2.3	74.2	72.2	73.1
General Math + Algebra I + Geometry	15.6	17.4	16.5	72.9	70.6	71.7
General Math + Algebra I + Algebra II	3.0	3.3	3.2	66.2	61.6	63.8
Algebra I + Geometry + Algebra II	7.1	5.8	6.5	88.1	84.4	86.4
General Math + Algebra I + Geometry + Algebra II	24.0	17.7	20.8	83.8	80.6	82.4
TOTALS	100.0*	100.0*	100.0*	68.6	63.9	66.3

* Includes 2.6 percent boys, 2.1 percent girls, and 2.3 percent of the total who completed other course combinations.

Source: California State Department of Education, 1978.

Teacher Preparation and Licensing, is noted to be an exemplary research project documenting the relationship between time in instruction and student achievement. It concluded:

> Academic learning time is an important predictor of student achievement. Allocated time, engagement rate, and success rate of school activities are all associated with student achievement. Students who accumulate more academic learning time generally have higher scores on achievement tests.

Academic Learning Time is defined operationally in the BTES as the time a pupil is engaged in the study of relevant content that she/he can learn making no more than chance errors.

The BTES study also concluded:

> Research evidence accumulated over the past 36 years shows consistent positive relationships between time on task and achievement. When we find 16 studies that differ in virtually every aspect of design and yet yield consistent positive results, we can be very confident that the relationships found are real and enduring. Although some correlations between achievement measures and on-task time are as high as .87, the majority are in the range from .30 to .50, thus accounting for nine to 25 percent of the achievement variance. Virtually all the significant relationships found in the two phases of the BTES also fall into this range. These results clearly demonstrate that schooling does make a difference. (Denham and Lieberman, 1980)[1]

Mean Number of Years of Math and Science. Recognizing the relationship between the time spent in coursework and student achievement, it is useful to examine trends in course enrollment in math and science. Data collected from college-bound high school seniors in California taking the SAT indicated that there was a slight increase in the mean number of years of math taken by this group from 1972 to 1981. While in 1972-73 they took an average of 3.01 years; in 1980-81, they studied math for an average of 3.29 years. In both biological sciences and physical sciences, California seniors in 1980-81 had taken slightly more years of coursework than they had in 1972-73 (1.32 versus 1.29 years in biological sciences and 1.33 versus 1.08 years in physical sciences). The number of years of sciences taken, however, is below the peak achieved in 1975-76. See Table V-2.(Admissions Testing Program of the College Board, 1971-1981)

TABLE V-2

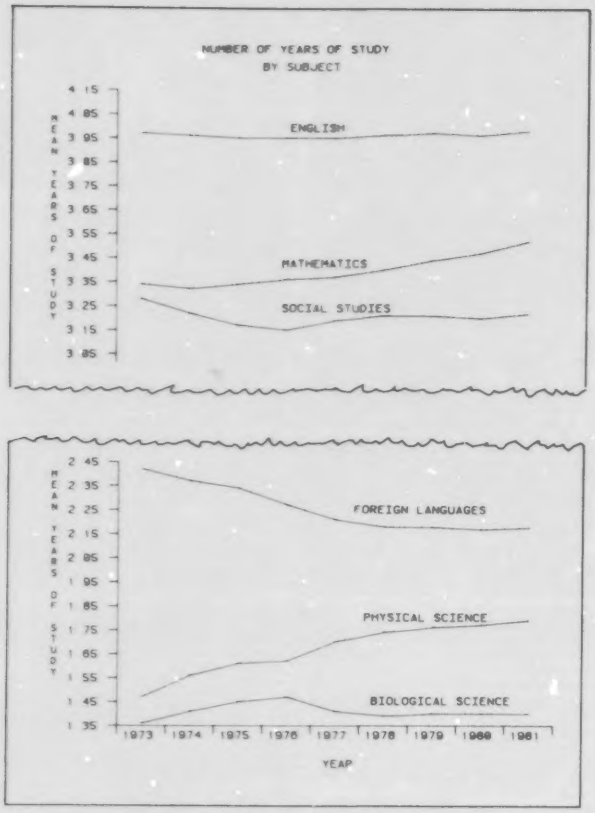
MEAN NUMBER OF YEARS OF STUDY
BY CALIFORNIA STUDENTS
BY SUBJECT

	Mathematics	Biological Sciences	Physical Sciences
1972-73	3.01	1.29	1.08
1973-74	3.0	1.34	1.32
1974-75	3.01	1.39	1.41
1975-76	3.02	1.40	1.41
1976-77	3.05	1.34	1.28
1977-78	3.07	1.34	1.27
1978-79	3.18	1.35	1.32
1979-80	3.23	1.33	1.32
1980-81	3.29	1.32	1.33

Source: Compiled from Admissions Testing Program of the College Board, 1971-81.

National data show that the average number of years of math and physical science taken by high school students taking the SAT has increased fairly steadily since 1972-73 and is currently about 3.5 and 1.8 years, respectively. The amount of biological science taken by seniors taking the SAT in 1980-81, about 1.4 years, also exceeded the amount taken by those taking the test in 1972-73, although the level was down from its 1975-76 high. See Figure V-1. In all three subjects, therefore, California students took an average of fewer years than did students nationwide, with the largest difference being in the physical sciences where the difference

FIGURE V-1



is almost a half year. (Admissions Testing Program of the College Board, 1971-1981)

The fact that proportionally more California students take the SAT than do students nationwide makes evaluation of these figures difficult. The data reflect only students taking the SAT who voluntarily report their coursework. A greater number of marginal students, as opposed to top students, report their coursework in states where more students take the tests, bringing down the mean in these states.

Apparently, the slight increases in mean years of study were too small to counteract other forces that resulted in the declines in mean SAT scores during many of the same years as mean years of coursework increased.

Enrollment Per Population. Another way of assessing the exposure of students to math and science is to look at the percentage of students enrolled in science and math courses. No historical data on this topic could be located for California, and research on historical U.S. data revealed contradictory findings. While the National Science Foundation (NSF) study reported a downward trend in the percentage of U.S. students taking math and science since 1960 , the National Research Council (NRC) found that these figures were relatively stable after 1960 (National Science Foundation, 1980) (National Research Council, 1979). Differences in identifying what courses should be counted as math and science may account for this discrepancy.[2]

Recent data are available that compare the enrollment of California students in mathematics with students nationwide. They show that the percentage of California seniors taking various math courses increased from 1978-79 to 1979-80. The same trend is revealed for the nation. When the data for California students and students nationwide are compared for 1979-80, the percentages of students in California taking Algebra I or II or Geometry were slightly higher than the national percentages and the percentage taking calculus was about the same. In California, a slightly smaller percentage of students took physics, trigonometry, and chemistry than took them nationwide. These data are limited in that they do not cover coursework such as biology, earth science, and oceanography. See Tables V-3 and V-4. (California State Department of Education, 1979)

TABLE V-3

PERCENTAGES OF 17-YEAR-OLDS IN THE NATION AND TWELFTH GRADERS IN CALIFORNIA TAKING VARIOUS MATHEMATICS COURSES

1978-1979

Mathematics Course Taken	Percent who reported they had taken course	
	Nation's 17-year-olds	California's twelfth graders
General math only	(not available)	24
Algebra I	72	73[a]
Geometry	51	46[a]
Algebra II	37	31[a]
Trigonometry	13	5[b]
Probability and statistics	3	(less than 1%)[b,c]
Precalculus	4	2[b]

[a] These percentages do not include 2.3% who took unconventional course combinations.

[b] These data are based upon the number of students shown in the October Report for 1977-78. The percentages were computed by dividing the number enrolled in the courses by number of twelfth-grade students tested in 1977-78 (244,233).

[c] The actual percentage is 18.

Source: California State Department of Education, 1979.

TABLE V-4

PERCENTAGE OF HIGH SCHOOL SENIORS TAKING MATHEMATICS AND SCIENCE COURSES 1979-80

Course	In the Nation	In California
Algebra I	77.9	79.3
Algebra II	47.8	48.9
Geometry	54.4	56.7
Trigonometry	24.9	24.0
Calculus	7.9	7.9
Physics	20.5	17.2
Chemistry	37.5	32.2

Note: This table was produced from data collected by the National Center of Educational Statistics as part of its study, High School and Beyond, 1981.

Source: California State Department of Education, 1981.

Enrollment in Advanced Science and Math Courses. Another revealing measure of the preparation of high school students is enrollment in advanced science and math courses. Recent increases in the percentage of California students who take substantial numbers of years of academic coursework have been said to be a reason why their SAT scores have improved recently among California students. Among California students taking the SAT, there was a

ten percent increase in males and a 16 percent increase in females who took four or more years of math in high school in 1980-81 over 1972-73. There was a slight decrease in the number of males and a slight increase in the number of females taking three or more years of biological science, and a four percent increase in the number of both males and females taking three or more years of physical science. See Tables V-5 to V-7. (Admissions Testing Program of the College Board, 1971-1981)

TABLE V-5

FOUR OR MORE YEARS OF MATHEMATICS
1972-73

California		U.S.	
Male	Female	Male	Female
47%	22%	60%	37%

THREE OR MORE YEARS OF BIOLOGICAL SCIENCES, 1972-73

California		U.S.	
Male	Female	Male	Female
7%	6%	7%	5%

THREE OR MORE YEARS OF PHYSICAL SCIENCES, 1972-73

California		U.S.	
Male	Female	Male	Female
11%	3%	21%	8%

Source: Compiled from Admissions Testing Program of the College Board, 1972-1973.

Nationwide, seven percent more males and 13 percent more females took four more years of math in 1980-81 than in 1972-73; there was only a slight increase in the number of males and a two percent increase in the number of females taking three or more years of biological sciences, and a ten percent increase in the number of males and a 9 percent increase in the number of females taking three or more years of physical sciences. See Tables V-5 to V-7. (Admissions Testing Program of the College Board, 1971-1981)

TABLE V-6

FOUR OR MORE YEARS OF MATHEMATICS
1976-77

California		U.S.	
Male	Female	Male	Female
48%	26%	66%	40%

THREE OR MORE YEARS OF BIOLOGICAL SCIENCES, 1976-77

California		U.S.	
Male	Female	Male	Female
7%	7%	8%	9%

THREE OR MORE YEARS OF PHYSICAL SCIENCES, 1976-77

California		U.S.	
Male	Female	Male	Female
15%	7%	28%	14%

Source: Compiled from Admissions Testing Program of the College Board, 1976-1977.

When California is compared with the nation, there is a dramatic difference in the number of advanced courses taken by students. In 1980, 57 percent of California males compared with 67 percent of males nationwide took four years of math; 38 percent of California females compared with 50 percent of females nationwide did so. About six percent of male and female California students took three or more years of biology, compared with nearly eight percent of both sexes nationwide. In the physical sciences,

TABLE V-7

FOUR OR MORE YEARS OF MATHEMATICS
1980-81

California		U.S.	
Male	Female	Male	Female
57.2%	38.1%	67.3%	50.5%

THREE OR MORE YEARS OF BIOLOGICAL SCIENCES, 1980-81

California		U.S.	
Male	Female	Male	Female
6.4%	6.4%	7.9%	7.5%

THREE OR MORE YEARS OF PHYSICAL SCIENCES, 1980-81

California		U.S.	
Male	Female	Male	Female
15%	7%	31.3%	16.6%

Source: Compiled from Admissions Testing Program of the College Board, 1980-1981.

only 15 percent of male California students took three or more years compared with over 31 percent of male students nationwide. Only seven percent of female California students took three or more years compared with almost 17 percent nationwide. See Table V-7. (Admissions Testing Program of the College Board, 1981)

These data may be somewhat misleading because a larger percentage of California seniors take the SAT than do nationwide. More marginal students are therefore included in California's averages than are included in the nationwide averages.

An explanation of why many students elect not to pursue advanced courses was given by a student interviewed for the NSF study. The student said:

> When you do get into higher math and science stuff, sometimes you feel unless you're really going to continue and be a physicist or something, there's no reason to take it because you're never going to use it. Unless you're planning on climbing the ladder and be way up there. It's practical to stop. (National Science Foundation, 1979)

As part of its longitudinal study, High School and Beyond, the National Center for Education Statistics collected data on how many years of math and science were taken by high school seniors. These data reflect noncollege-bound as well as college-bound students. See Table V-8. They show California students taking substantially lower numbers of advanced courses; however, according to the California Department of Education, these numbers could be misleading because students' responses included all mathematics work, including remedial math, and the High School and Beyond data showed that 27 percent of California students took remedial, basic, or essential mathematics compared with 31 percent of students nationwide. If it

is assumed that four percent more students take these courses nationwide than do in California, the number of years of math work taken in California becomes more comparable to that of the nation. (California State Department of Education, 1981)

High School Honors Courses. Enrollment figures for high school honors classes in science and math are another way of measuring participation in these subject areas. Care must be taken not to place too much weight on these percentages because the level of course considered an honors course varies greatly state to state and even from school to school.

TABLE V-8

PERCENTAGE OF 1979-80 HIGH SCHOOL SENIORS WHO HAD TAKEN SPECIFIC NUMBERS OF YEARS OF MATHEMATICS AND SCIENCE COURSE WORK

Number of Years of course work	Mathematics		Science	
	In the Nation	In California	In the Nation	In California
One year or more	92.2	90.3	89.2	87.2
Two years or more	64.9	58.2	51.5	41.3
Three years or more	31.4	25.6	21.6	13.3

Source: National Center for Educational Statistics. As cited in California State Department of Education, 1981.

As shown in Table V-9, a slightly greater percentage of California students who took the SAT in 1981 said they had taken honors courses in math and science than did those who took the exams in 1972. The figure is, however, below its peak of 1976. (Admissions Testing Program of the College Board, 1971-1981)

TABLE V-9

PERCENTAGE OF CALIFORNIA STUDENTS TAKING
THE SAT EXAM
WHO TOOK HONORS COURSES

Year	Mathematics	Biological Sciences	Physical Sciences
1972	10.9	5.5	5.0
1973	10.9	5.5	5.0
1974	12.9	7.5	6.6
1975	14.4	7.5	7.0
1976	15.4	8.5	7.5
1977	11.9	7.0	6.0
1978	11.0	7.0	6.0
1979	12.7	7.0	6.7
1980	11.6	6.5	6.1
1981	12.0	6.6	6.4

Source: Compiled from Admissions Testing Program of the College Board, 1971-81.

Nationwide, the number of students taking the SAT in 1981 who said they had taken honors courses in math and science is also larger than the number reporting honors courses in 1972, but down from the number saying they took such courses in 1976. See Table V-10.

While the percentage of California students enrolled in honors courses in 1972 equalled or exceeded the national enrollment in all three subject areas, by 1981 California students lagged behind the nation in all areas. In addition to math and science, California lagged behind the nation in other honors areas: English, foreign languages and social studies. The

differences were smallest in English and most pronounced in the physical sciences. (Admissions Testing Program of the College Board, 1971-1981) It should be remembered that a larger proportion of California students than students nationwide take the SAT on which this question is asked, which distorts these data.

TABLE V-10

PERCENTAGE OF U.S. STUDENTS TAKING THE SAT EXAM WHO TOOK HONORS COURSES

Year	Mathematics	Biological Sciences	Physical Sciences
72-73	9.0	5.0	5.0
73-75	14.5	9.5	9.0
1976	16.4	10.5	10.0
1977	14.4	9.5	9.0
1978	14.0	9.0	9.0
1979	14.5	9.4	9.8
1980	13.8	9.0	9.3
1981	14.0	9.2	9.6

Source: Compiled from Admissions Testing Program of the College Board, 1971-81.

High School Graduation Requirements

A factor that undoubtedly affects the number of science and math courses that students take is high school graduation requirements. Unlike most states, the State of California does not set minimum high school graduation requirements and has not done so since 1969. Local school districts establish their own requirements. The minimum level has generally

been to provide an academic background that enables students to meet university and college entrance requirements. The entrance requirements for the California State Universities and Colleges (CSUC) system provide the base level; more rigorous standards are aimed at qualifying graduates for entrance into the UC system. Table V-11 provides a sample of graduation requirements of high schools in the San Jose area.

Nationwide, there has been a trend since 1970 toward a reduction in the coursework required for high school graduation. Graduation requirements are significantly greater in social studies than in science or math. See Table V-12.

TABLE V-11

SCIENCE-MATH REQUIREMENTS FOR HIGH SCHOOL GRADUATION

District	Years of Science	Years of Math
Campbell	½	1
East Side	1	2
Fremont	1	1
Gilroy	1	1
Los Gatos	1	1
Milpitas	2	*4
Morgan Hill	1	1
Mtn. View-Los Altos	1	1
Palo Alto	2	*1½
San Jose	1	1
Santa Clara	1	1

* Requirements apply to graduating class of '85.

Source: San Jose Mercury, 1982.

TABLE V-12

PERCENT OF SCHOOL DISTRICTS REQUIRING MINIMUM AMOUNTS OF GRADE 9-12 INSTRUCTION IN EACH SUBJECT

	Less Than 1 Year	1 Year	More Than 1 Year	Unknown
Science	2	54	33	11
Mathematics	4	47	33	16
Social Studies	2	5	74	20

Source: Weiss, 1977.

University and College Admissions Requirements

According to Michael Kirst, past President of the California State Board of Education and Professsor of Education at Stanford University, CSUC and UC admissions requirements have tended to encourage or at least rationalize the reduction of academic courses offered by California's high schools. From 1966 to 1984, CSUC has and will require a 2.7 grade point average (GPA) and a qualifying score on the SAT (from which any student achieving over a 3.2 GPA is exempt). The result has been, Kirst said, to discourage high school students from taking rigorous academic courses in which good grades are more difficult to achieve. (Kirst, 1981)

Until 1966, CSUC required for admission 14 semester courses in academic subjects, with no courses specified. This requirement was dropped in 1966 because it was believed that most students would take that number of academic courses even it they were not required to do so for college

admission. When it recently became apparent that this was not the case, CSUC instituted entrance requirements of four years of college-preparatory English and two years of college-preparatory math. (Bess, 1982)

The UC system has required preparation in subject areas for admission to the University since the 1930s, including two years of math, one year of laboratory science, four years of English, one year of history, two years of foreign language, and one advanced class in either math, science, or foreign language. The entering student must have a GPA of 3.33.[3]

The Board of Admissions and Relations with Schools has approved increasing the math requirement from two to three years, citing inadequate preparation in mathematics that has caused special problems for students entering the University. The report to the Policy Committee to Assist Underprepared Students said:

> Because UC requires only two years of mathematics for admission, and because many students now begin taking algebra in the 8th grade, it is possible for students to finish three years of math in the 10th grade, have no practice after that, and arrive at the University having forgotten virtually all they learned. As one professor put it, 'Maybe a hypnotist could bring it out, but I can't.' (University of California, 1981)

The proposal must be approved by the Academic Senate and the Board of Regents before it is implemented.

Declining standards for UC graduation are also believed to have had a negative effect on high school standards. As reported by Kirst, UC Assistant Vice President Alice Cox, in a meeting with the State Board of

Education, noted that, when UC reduced its undergraduate requirements high schools followed suit and reduced their graduation requirements. The University now plans to raise its own graduation requirements but Cox warned that high schools that dropped third- and fourth-year academic courses several years ago are now frozen into a restrictive curriculum by fiscal constraints, and that high school standards may therefore be painfully slow to rise. (Kirst, 1981)

Availability and Quality of Teachers

Background. The critical importance of the teacher to student learning has been documented by numerous researchers. For example, reviews of three NSF-funded studies by the National Science Teachers Association concluded:

> The studies found, not surprisingly, that within any classroom the science taught and the way it is taught is dependent primarily on what the individual teacher believes, knows and does. Numerous studies indicate that the type of instruction does affect student learning and that the teacher is the most important instructional variable. The critical role of the teacher in instituting changes in science teaching is well documented. (National Science Foundation, 1979)[4]

Not only have teachers been proven important to learning, they have been shown to be important to career decisions as well. A study by Hauser, et al. showed the importance of the teacher to the student pursuing a college career. The largest direct influences on college plans and occupational aspirations were shown to be grades and the perceptions of significant others, including teachers, parents, and friends.

> A standard deviation shift in grades gives rise to an eight-percentage-point shift in the likelihood that a student will plan to attend college and a

> 4.5 point shift in occupational status aspirations. Significant others have very large effects on college plans and occupational aspirations within schools. The chance of planning on college is increased 10.4 percentage points by the perception of teacher encouragement, 26.2 percentage points by the perception of parent encouragement, and 16.3 percentage points by the perception that most of one's friends will attend college. These same variables directly increase occupational aspirations on the Duncan SEI by 4.2 points, 8.4 points and 6.6 points, respectively. (Sewell and Hauser, 1975)

A report by the National Assessment of Educational Progress, Attitudes Toward Science, also documented the importance of the teacher in career decisions. It concluded:

> The most vital factors in a science classroom are the behavior of the teacher and the teacher's attitudes towards science. Many times people in science careers have pointed to one teacher who was the catalyst for their interest in science and in a science-related career. [National Assessment of Educational Progress, 1979(b)]

Current Availability and Quality of Teachers. Shortages of qualitied teachers of math and science will undoubtedly have a serious impact on the ability of California and the nation to prepare students for jobs and lives that are affected by the technological revolution.

A measure of the shortfall in the quantity and preparation of math and science teachers in California is the number of emergency credentials issued by the California Commission for Teacher Preparation and Licensing. The Board records credentials given for long-term assignments to teachers who are currently not teaching in the field in which the credential is given and who do not necessarily have college credits or experience in the subject. A look at the emergency credentials issued in 1980-81 revealed that mathematics was the subject in which teachers were in shortest supply,

with 170 long-term credentials issued. See Table V-13. (Commission for Teacher Preparation and Licensing, 1980-81)

TABLE V-13

SINGLE-SUBJECT TEACHING CREDENTIALS (EMERGENCY LONG TERM)

Subject	Frequency	Rank
Mathematics	170	1
English	157	2
Physical Education	71	3
Social Science	54	4
Music	32	5
Life Science	27	6
Foreign Language: Spanish	23	7
Physical Science	15	8
Art	11	9
Business	11	9
Home Economics	10	11
Industrial Arts	10	11
History	9	13
Foreign Language: French	4	14
Foreign Language: Portuguese	3	15
Agriculture	2	16
Foreign Language: German	2	16
Foreign Language: Hebrew	1	21
Foreign Language: Latin	1	21
Foreign Language: Russian	1	21
Health Science	1	21

Source: Commission for Teacher Preparation and Licensing, 1980-81.

Examining the distribution of the credentials reveals that, in California, Los Angeles Unified School District (LAUSD) is by far the most seriously affected by the shortages, with 91 of the 170 long-term credentials being issued to it. More detailed information on LAUSD indicated that, in addition to 92 long-term emergency licenses, another 78 limited-term licenses were issued for math teachers. (Statewide data do nct

break down limited-term credentials by subject.) According to standards set by LAUSD for its emergency credentials, a teacher must have a minimum of ten college units in the field in which he/she is issued a long-term emergency credential before he/she can teach basic courses full time. A teacher who receives a limited emergency credential needs no background in the subject area and may teach one or two classes per day in the subject.[5]

The LAUSD reported that the teacher shortage was even more critical in 1981-82 than in 1980-81. While in 1980-81 a total of 169 long-term and limited emergency credentials were issued in math, in 1981-82 a total of 333 were issued. Whereas in 1980-81 only nine long- and limited-term emergency assignments were made in science, in 1981-82, 82 were made. (Moffett, 1982)

A 1978 survey of 465 Bay Area science teachers by California State University-San Jose found that 16 percent of them had not majored in science in college. (Beard, 1982)

National data show that teacher shortages in math and in some sciences are a widespread problem that has become more severe over time. An annual survey conducted since 1976 for the Association for School, College, and University Staffing, a 700-member professional organization for university placement officials and school personnel administrators, shows mathematics to be the area of greatest shortfall, one that has become progressively worse since 1976. Physics takes second place, also with a worsening situation since 1976. See Table V-14. (Association of School, College, and University Staffing, 1982)

Surveys conducted in 1980 and 1981 by Howe and Gelovich of the 50 state science supervisors to assess supply and demand for secondary school science and math teachers indicated shortages in 1980 that became worse in 1981. Twenty-one states reported a critical shortage of physics teachers in

TABLE V-14

RELATIVE DEMAND BY TEACHING AREA AND YEAR
CONTINENTAL UNITED STATES

	1982	1981	1980	1979	1978	1976
Teaching fields with considerable teacher shortage		**(5.00-4.25):**				
Mathematics	4.81	4.79	4.80	4.68	4.40	3.86
Science-Physics	4.41	4.56	4.28	4.36	3.91	4.04
Industrial Arts	4.36	4.72	4.77	4.68	4.65	4.22
Vocational Agriculture	4.36	4.46	4.73	4.67	4.69	4.06
Teaching fields with slight teacher shortage		**(4.24-3.45):**				
Special Education (learning disabled)	4.20	4.47	4.48	4.50	4.45	4.00
Bilingual Education	4.13	4.10	4.21	4.32	–	–
Science-Chemistry	4.13	4.42	4.18	4.09	3.97	3.72
Special Education (emotionally disturbed)	3.98	4.22	4.36	4.22	3.96	3.42
Speech Path/Audiology	3.95	4.27	4.17	3.83	3.83	3.68
Special Education-Multi. Handicapped	3.93	4.13	3.87	3.24	–	–
Science-Earth	3.89	4.08	3.64	3.82	3.50	3.44
Data Processing	3.56	–	–	–	–	–
Special Education (mentally retarded)	3.84	4.14	4.23	4.39	3.52	2.87
Special Education-Gifted	3.81	4.10	4.33	4.56	3.95	3.85
Special Education-Reading	3.73	4.21	4.23	4.27	4.09	3.96
Science-Biology	3.66	3.98	3.50	3.49	3.11	2.97
School Psychologist	3.56	3.70	3.87	3.43	3.68	3.09
Business	3.47	3.50	3.80	3.65	3.52	3.10
Teaching fields with balanced supply and demand		**(3.44-2.65):**				
Music-Instrumental	3.28	3.33	3.65	3.33	3.30	3.03
English	3.21	3.37	3.51	2.78	2.30	2.05
Library Science	3.12	3.31	3.58	4.26	–	–
Music-Vocal	2.95	3.06	3.32	2.97	3.03	3.00
Counselor-Secondary	2.79	3.13	3.76	3.03	3.31	2.69
Driver's Education	2.77	2.87	2.96	3.06	2.63	2.44
Speech	2.76	2.65	2.50	2.47	2.48	2.46
Counselor-Elementary	2.72	3.05	3.38	2.96	3.00	3.15
Language, Modern Spanish	2.68	2.95	3.34	2.88	2.84	2.47
Teaching fields with slight suplus of teachers		**(2.64-1.85):**				
Journalism	2.61	2.77	2.96	2.50	2.54	2.85
Language, Modern French	2.49	2.58	2.68	2.49	2.15	2.15
Language, Modern German	2.48	2.58	2.70	2.17	2.28	2.03
Home Economics	2.43	2.54	2.85	2.67	2.37	2.62
Social Worker (School)	2.34	–	–	–	–	–
Elementary-Intermediate	2.26	2.56	2.84	2.33	1.97	1.90
Social Science	2.11	2.05	1.96	1.83	1.51	1.51
Elementary-Primary	2.02	2.24	2.77	2.19	1.84	1.78
Health Education	1.90	2.24	2.17	2.16	2.38	2.27
Teaching field with considerable surplus of teachers		**(1.84-1.00):**				
Art	1.85	2.00	2.45	2.06	1.72	2.14
Physical Education	1.72	1.80	1.82	1.67	1.86	1.74

Source: Association of School, College and University Staffing, 1982.

Key 5 = Greatest Demand 1 = Least Demand
Based upon a survey of teacher placement officers

1980, while 27 reported a critical shortage in 1981. Sixteen states reported a critical shortage of math teachers in 1980, while 18 said their shortage was critical in 1981, and ten states said they had a criticial shortage of chemistry teachers in 1980, while nine said they had such a shortage in 1981. See Table V-15. (Klein, 1982)

TABLE V-15

NUMBER OF STATES REPORTING IN 1980 AND 1981

	Critical Shortage		Shortage		Adequate Supply		Surplus	
Subject	1980	1981	1980	1981	1980	1981	1980	1981
Physics	21	27	22	15	3	4	2	1
Math	16	18	19	25	7	2	4	1
Chemistry	10	9	25	29	9	6	5	2

Source: Klein, 1982.

National surveys have revealed substantial numbers of teachers who are teaching math and science but who are not trained in these fields. A National Science Teachers Association (NSTA) survey conducted in December 1981 gathered information from secondary school principals on how many newly employed science and math teachers were hired on an emergency basis because qualified teachers could not be found. The survey found that over 50 percent of the teachers were employed on an emergency basis. The number was highest in the Pacific states, where the survey found 84 percent of newly

TABLE V-16

NEWLY EMPLOYED
SCIENCE AND MATH TEACHERS
EMPLOYED ON AN
EMERGENCY BASIS

Census Region	Percentage
Pacific States	84%
Mountain States	23%
West North Central States	43%
West South Central States	63%
East North Central States	46%
East South Central States	40%
North East States	9%
Atlantic States	43%
South Atlantic States	50%

Source: Klein, 1981.

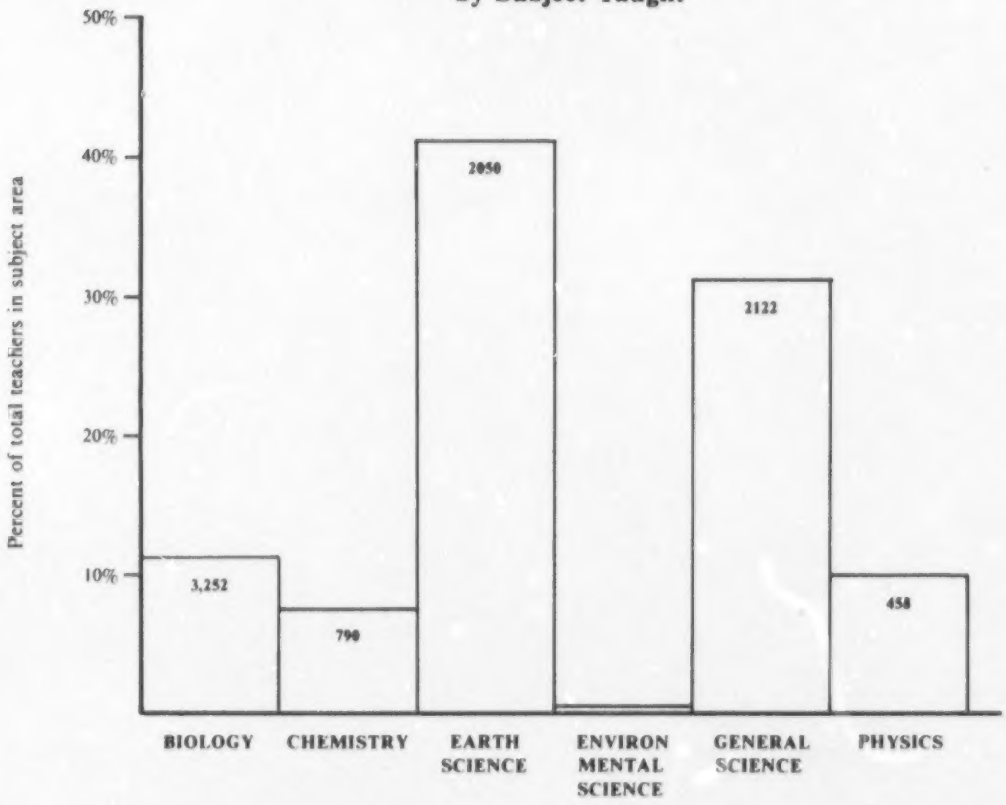
employed teachers to be hired on an emergency basis. See Table V-16. (Klein, 1982)

A Spring 1981 survey by NSTA showed that, of a sample of 59,446 teachers who teach science 50 percent of the time or more, 10,730, or 18 percent, were nonscience majors. Twenty-six percent of these nonmajors were math majors, 24 percent were physical education majors, 11 percent were social studies majors, seven percent were home economics majors, and the rest held other majors. The survey found that 30 percent of the nonmajors taught biology, seven percent taught chemistry, 19 percent taught earth sciences, 20 percent taught general science, and four percent taught physics. (National Sciences Teachers Association, 1982) The number of nonmajors compared with total teachers teaching in the various subject areas is shown in Figure V-2.

FIGURE V-2

SCIENCE TEACHERS WITHOUT SCIENCE MAJORS

by Subject Taught



1) Source: Survey of 59,446 teachers who teach science 50% or more of the time by National Science Teachers Association, 1981.

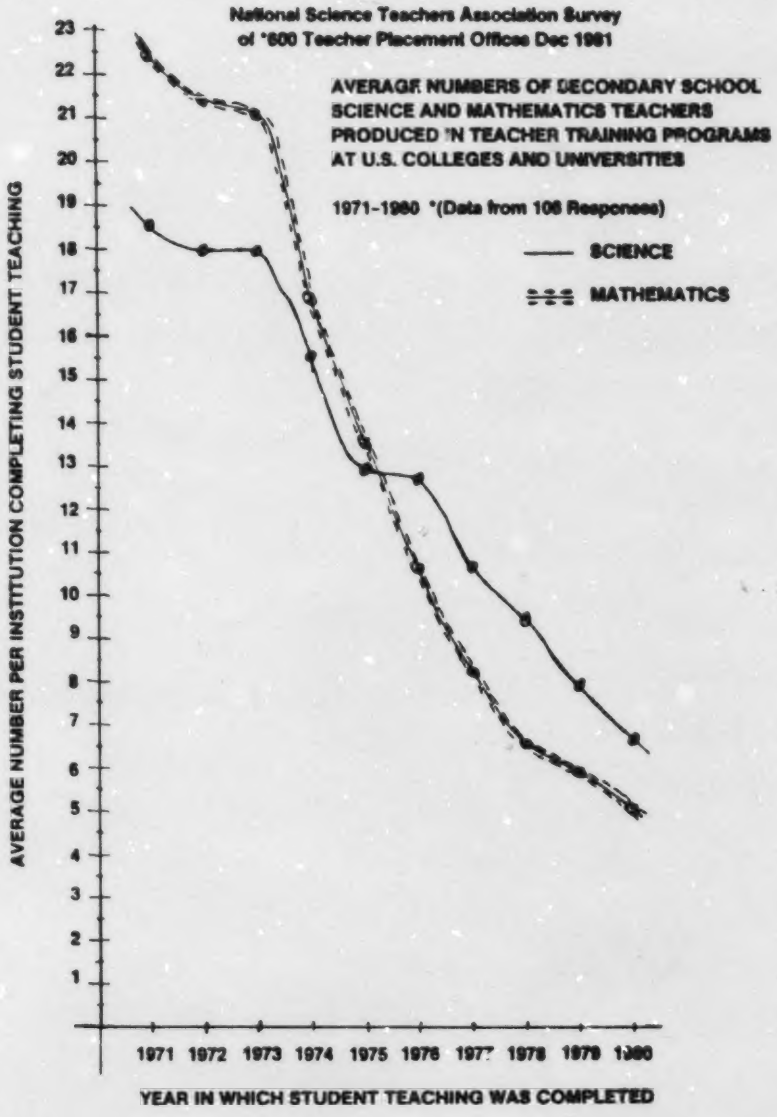
A 1977 survey of teachers revealed that a sizeable number believe they are inadequately qualified to teach one or more of their courses. Over ten percent of seventh- to ninth- grade math teachers and five percent of tenth- to twelfth-grade math teachers said they feel inadequately qualified, while about 12 percent of both seventh- to ninth-grade and tenth- to twelfth-grade science teachers said they feel inadequate. (Weiss, 1977)

Outlook for Future Availability. All indications point to a worsening of the shortage of math and science teachers. A recent survey by UC-Berkeley's Department of Education showed a total of 92 students currently preparing in California's public universities and colleges to be math teachers, and 164 students preparing to be science teachers. In the opinion of James Guthrie, Chairman of the Education Department at UC-Berkeley, public and private teacher training institutions in California will probably produce, at best, half of the math teachers needed in the short-term future. Guthrie based his estimate on the large number of teachers retiring and leaving education for industry and the small number of teachers currently being trained. The assessment of students currently being trained does not include California State University-San Jose, one of the state's major training institutions which educates approximately ten percent of the state's teachers. (Guthrie, 1982)

The LAUSD, which currently is seeking 200 math teachers, recently surveyed ten area colleges and universities that train math teachers and found 15 possible candidates for the jobs. (Moffet, 1982)

Declining numbers of students pursuing degrees in science or math education appears to be a national phenomenon. The Conference Board of the Mathematical Sciences reported in 1981 that, whereas in 1974-75 4,773 bachelor's degrees in secondary teaching in mathematics were awarded, in 1971-80 37 percent as many, or only 1,752, were given. (Conference Board of the Mathematical Sciences, 1981) A survey by NSTA also documented the dramatic decline in average numbers of science and math teachers being produced in teacher training programs. (Klein, 1982) See Figure V-3.

FIGURE V-3



Experts expect the shortage to become worse if steps are not taken to attract new, retain existing, and return credentialed teachers not now teaching to teaching positions. The NSTA survey showed that schools have an aging faculty. Perhaps an even larger problem is loss of teachers to industry. The NSTA study revealed that almost five times as many science and math teachers left teaching last year for employment in nonteaching jobs

as left due to retirement, and that one in four of the younger faculty said they plan to leave teaching completely. (Klein, 1982) Ironically, it may be that the spurt in high-technology growth will draw more science and math teachers to industry just at the time when they are most needed in the classroom.

The salaries offered by industry are far more lucrative than teachers' salaries. The National Education Association reported that the average salary for beginning teachers with a bachelor's degree in 1978-79 was 73.1 percent of the average beginning salary offered in 1978 by private industry to bachelor's degree graduates in mathematics and statistics. (Graybeal, 1979) "You have to be either financially self-sufficient or crazy to go into science teaching," a student teacher in California is quoted as telling Newsweek.

More attractive financial offers by industry are not the only reason teachers are leaving teaching and students are choosing to pursue math and science majors other than education. "The whole image of public education is so bad that no one wants to go into the field. Industry can take off the cream of the crop," Viggo Hansen, a Professor of Mathematics Education at CSU-Northridge is quoted as saying in the Los Angeles Times. "Teachers used to beget teachers, but the parents who are teachers are often so fed up they are advising their children against it." Other reasons behind the shortage include problems with school discipline, misconceptions that teacher surplus in some areas imply surplus in all areas, and increased opportunities for women in other professions.

Zalman Usiskin of the University of Chicago believes that the high school math curriculum — both its content and the way it is taught -- has helped cause the shortage. According to an article in Education Week,

Usiskin said that negative experiences with their own math educations in secondary school may have led prospective math teachers to choose against teaching math. He related two periods of teacher shortages with periods in which curriculum was out-of-date, teachers relied on classroom drill, and the focus was on improving the performance of slower students. In comparison, the 1960s -- the only era in which there was an adequate supply of math teachers -- was an era of innovation and had a focus on the brighter students. (Walton, 1982)

Quality of Texts, Materials, and Curriculum

Background. Textbooks have been found to be an important factor in student learning. Jeanne S. Chall, Professor of Education at Harvard University, found a relationship between declining SAT scores and the declining difficulty of the textbooks that students were exposed to from elementary school onward. Chall, at the request of the College Board's Advisory Panel on Score Decline, conducted a study in 1977 to find out whether textbooks had changed during the years that SAT scores declined (at that time, 1967-1975) and whether the changes were related to SAT verbal score decline. The researchers analyzed reading selections from the SAT and the textbooks most widely used during the period, judging their difficulty by various indices. They then simulated a series of six longitudinal studies of six groups of students who entered first grade during specified years, were exposed to the textbooks during grades 1-11, and took the SATs in their senior years.Chall concluded that, while the study's findings were highly suggestive:

> There seems to be rather compelling evidence that a positive relationship exists between the level of challenge of textbooks used by pupils and the scores they achieve on the SAT-verbal tests. The

> relationship seems to be stronger for the elementary as compared to the high school years, and for the earlier as compared to the later elementary grades. (Chall, 1977)

Texts. While there has been no systematic study of science and math texts, anecdotal evidence suggests that the texbooks used in both California and in the rest of the country have declined in difficulty in recent years. Michael Kirst, the former president of the State Board of Education, estimated that the textbooks currently in use are about two grade levels below those used 10-15 years ago. (Kirst, 1981) The NSF report came to a similar conclusion:

> ...there is evidence that teachers and committees purchasing textbooks are so sensitized to reading difficulties that they are acquiring textboks in the content fields taught in the higher grades that have a simplified vocabulary and sentence structure. In mathematics, the situation is similar. Schools are demanding textbooks that concentrate on drill and computation at the expense of common applications even in the higher grades. (National Science Foundation/Department of Education, 1980)

The NSF report went on to say that simplification of textbooks may be a mistake:

> It is not clear that such practices are warranted. Tests show that children have mastered the basic techniques of reading, but have trouble with comprehension and interpretation. Similarly, children can do simple whole number computations, but have trouble solving common problems. (National Science Foundation/Department of Education, 1980)

Numerous explanations have been advanced for the decline in textbook difficulty. The most popular is that schools sought downgraded textbooks during the 1960s and 1970s when money was made available by Congress for the purchase of educational materials for programs for the disadvantaged — many

of whom could not read at grade level. The proliferation of elective courses that did not require substantive textbooks is another possible reason.

Following Chall's 1977 study that linked the declining difficulty of textbooks with declining SAT scores, the attitudes of schools and publishers began to turn around. "I first heard Jeanne Chall talk about the need for more difficult books about five years ago," a senior editor from Holt, Rinehart & Winston is quoted as saying in a recent Los Angeles Times article:

> ... I would say it is only in the last year or so that we have perceived a willingness in the marketplace to accept books at grade level and not one or two levels below. That means we're just beginning to produce these books, which means, in turn, that it will be three or four years before the kids get them.

The California Board of Education, which approves textbooks for kindergarten through eighth grade, is currently involved in a policy debate involving whether or not it should refuse to approve textbooks on the grounds of their not being difficult enough. Another current issue is whether or not there should be more control over the texts used in grades nine through twelve.

Curriculum. The texts, other learning materials, and course content that comprise the curriculum of science courses were criticized in the NSF study for paying almost exclusive attention to the preparation of junior and senior high school students for future course work leading to professional careers in science.

The NSF study stated:

> The emphasis is heavily on the pure structure of the discipline form of science. Very little in

> the content of courses provides information related to personal or societal problems, about technology and what engineers do, or to vocational relevance except to those students interested in professional science careers. (National Science Foundation/Department of Education, 1980)

The nine organizations that reviewed the NSF studies expressed concern about this emphasis. The National Science Teachers Association, for example, said, "...much of the secondary school science curriculum is mismatched to the interests and needs of the majority of students in our schools who will not pursue scientific or technological careers." (National Science Foundation/Department of Education, 1980)

Materials. Equipment also affects the quality of education. A survey of 135 science teachers and resource specialists in California indicated that laboratory equipment ranked third out of 11 items in the priority that the respondents placed on improving it. Computer equipment placed fourth. The first two categories of need identified by the teachers were; teacher-training skills and strategies, and teacher-training content update. (Rice, 1982)

Nationwide, a 1977 survey of science, math, and social studies education revealed that 52 percent of math teachers and 66 percent of science teachers said that insufficient funds for purchasing equipment and supplies was a "serious problem" or "somewhat of a problem." Sixty percent of math teachers and 68 percent of science teachers claimed that lack of materials for individualizing instruction were a "serious problem" or "somewhat of a problem" and 33 percent of math teachers and 44 percent of science teachers called out-of-date teaching materials a "serious problem" or "somewhat of a problem." (Weiss, 1977)

The 1981 NSTA survey showed that 60 percent of science teachers reported cuts in their budgets for supplies and equipment. Said NSTA: "These cuts occur at a time when school labs are already obsolete and when computers and other components of modern electronics are essential in an up-to-date curriculum." (Klein, 1982)

Conclusion: The Problem of Funding

The ability of schools to offer courses, employ teachers, and purchase texts, laboratory materials, and computers hinges partly on funding.

Recent data from the National Education Association, as reported by the California Department of Education, indicated that California slipped from 26th to 44th in the nation in total expenditures for education as a percentage of personal income between 1973 and 1979.

Proposition 13 has taken a toll on California's public schools. About $2.7 billion was eliminated from school budgets as a result of the 1978 initiative. The state restored about $2 billion from state monies and made up the difference with ten percent cuts in all categorical programs, reduction of base support on a sliding scale from nine to 15 percent, narrowed support for adult education and elimination of most summer school programs. (Hunt, 1982)

A survey of 137 California school districts, including urban, rural, and suburban districts (but not LAUSD), concluded that science and math were among the programs cut as a result of Proposition 13.

- o Almost 19 percent reduced their science programs.
- o Over 12 percent reduced their math programs.

Ed Foglia, President of California Teacher's Association, said in an April 1981 press release, "It doesn't make sense to demand that our pupils do better while cutting the school day, and cutting down on basic reading, math, science, and other programs that the students need if they are to improve." (California Teacher's Association, 1981)

The impact of cuts in education proposed by the Reagan Administration could also affect science and math education. The California Department of Education estimates that if the proposed Reagan budget is adopted, California would lose 41 percent of its federal funding, or $400 million, by school year 1983-84. Federal money comprises almost ten percent of the total budget for California schools. Most of this federal money goes to "specialty" programs such as those for the handicapped and the gifted, and to innovative programs.

Footnotes

[1]Walker and Schaftanzick also concluded that exposure to curriculum relates to achievement. After examining achievement in 36 studies from 1957 to 1974 that compared students exposed to different curricula in the same subject, they said:

> Groups studying from innovative curriculum scored higher on virtually every test which favored the innovative curriculum, but groups studying from the traditional curriculum scored higher on a substantial number of comparisons in which the test content more clearly resembled what they had studied. (Walker and Schaffanzick, 1974)

In 1977, after reviewing academic achievement in 19 nations, Inkeles wrote:

> I could find no other characteristic of the school systems of the different countries which showed anything like the same strength of association with test scores as did the sheer time given to instruction and the related variables of opportunity to learn. (Inkeles, 1977)

[2]The NSF study reported that the proportion of students enrolled in science courses declined from 1960 to 1972-73 and that these low enrollment figures persisted until at least 1976-77. Data gathered for the NSF study indicated that, in 1960-61, 59 percent of ninth- to twelfth-grade students were enrolled in at least one science class. In 1972-73, less than 50 percent were enrolled, and in 1976-77, only 48 percent were enrolled. (National Science Foundation/Department of Education, 1980) The NSF study noted particular declines in chemistry and physics. Reasons given by school system personnel for these declines included reduced graduation requirements, more competition from other elective courses, the fact that these subjects could be picked up in junior college, and the perception of students that the courses were irrelevant. (National Science Foundation, 1979)

Data presented in a report by the National Research Council, however, indicated that the percentage of ninth- to twelfth-grade students registered in any science course was 48 percent in 1949 and increased to 66 percent in 1960-61 and to 67 percent in 1972-73. A small reduction was said possibly to have taken place during 1974-76. (National Research Council, 1979)

In math, the NSF report documented a decline in secondary math similar to that in science. (National Science Foundation/Department of Education, 1980) According to the NRC, however, in 1949 65 percent of the secondary school students in grades seven through twelve were enrolled in a math course. Seventy-three percent were enrolled in 1960, and 71 percent were enrolled in 1972-73. (National Research Council, 1979)

[3]The GPA requirement was raised from 3.0 to 3.3 in 1979, mostly to reflect grade inflation. The English requirement was raised from three to four years in Fall 1981.

[4]Other studies also document the importance of the teacher to student achievement. The Equal Opportunity in the Classroom Project, conducted by the Office of the Los Angeles County Superintendent of Schools and winner of an Educational Pacesetter Award from the National Advisory Council on Supplementary Centers and Service, is another study that indicated the importance of teacher behavior to student achievement. Participating were 742 elementary, middle, and secondary teachers from 30 school districts in Los Angeles County. Fifteen interactions that were supportive and motivating of students were identified by the reseachers, who tested and confirmed the hypothesis that teachers more often interact in a positive way with higher than with lower achievers. The 742 teachers were then divided into control and experimental groups. The experimental group participated in workshops where they learned behaviors supportive and motivating to students. The teachers then consciously practiced these behaviors in the classroom with both low and high achievers, with an observer recording the frequency of interactions with target students. After a three-year study, approximately 2,000 students identified as low achievers in the experimental classes showed statistically significant academic gains over their counterparts in the control classes. They also showed a significant reduction in absenteeism and discipline referrals, and even the high achievers in the experimental classes showed statistically significant academic gains over high achievers in the control group. (Kerman, 1977)

The Beginning Teacher Evaluation Study, conducted by the California Commission for Teacher Preparation and Licensing, came to the following conclusions about the importance of teacher behavior to student achievement. It determined:

- The teacher's value system is related to "academic learning time" (the time a student is engaged in study of relevant content that he/she can learn making no more than chance errors) and to student achievement. Teacher emphasis on academic goals is positively associated with student learning.
- The teacher's prescription of appropriate tasks is related to student achievement and student success rate.
- More substantive interaction between the student and an instructor is associatd with higher levels of student engagement.
- Academic feedback is positively associated with student learning.
- Structuring the lesson and giving directions on task procedures were positively associated with high student success.
- The teacher's accuracy in diagnosing student skill levels is related to student achievement and "academic learning time." (Denham and Lieberman, 1980)

[5]Teachers hired under nonemergency circumstances by the LAUSD need 20 units in the subject area to teach basic math, and 48 units to teach advanced as well as basic courses.

VI. COMPUTERS IN EDUCATION

According to industry officials, the use of computers as a classroom tool is growing and is expected to continue to extend enormously in the next decade. Just as general purpose computers will be as common in 1990 as stereo systems are today, so too will computers be a regular part of classroom equipment. High school computer literacy is becoming the "fourth R" in education, as evidenced by the figures.

The education sector will account for more than 20 percent of all U.S. desk-top computer expenditures and will continue to be one of the fastest growing markets for the microcomputer industry over the next decade, growing at an annual compounded rate of 31 percent between now and 1985. (Creative Strategies International, 1981)

TALMIS Inc., a microcomputer industry market research firm, estimates the total number of microcomputers currently in schools to be as high as 90,000. TALMIS Inc. predicts that by 1985 there will be as many as 400,000 microcomputers in the country's schools.

When considering the growth of computer use in education, one is also reminded of the decreasing costs. The average output of money for microcomputers used by schools is now between $1,700 and $2,000. Instructional programs, also known as software or courseware, range in price from $50 to $1,200. Experts say that the cost of both "hardware" (the computers) and software is dropping dramatically, thus becoming more affordable to a greater number of schools.

To date, colleges and universities have been the principal buyers of computer products in education and this will continue in 1982 and 1983, according to market analyses. There are currently 75,000 microcomputers in

use in higher education and it is expected there will be 430,000 in the next six years.

Figures published by Market Data Retrieval show that the number of computers used in California schools puts the state in the forefront of the nation. Table VI-1 shows that, of 1,048 school districts in California, 377 districts, or 35.97 percent, have at least one microcomputer. A total of 1,088 individual schools, or 14.75 percent of all the schools in the state, have one computer.

TABLE VI-1

DISTRICTS AND SCHOOLS IN CALIFORNIA THAT HAVE AT LEAST ONE MICROCOMPUTER

	Totals	With Micro-computers	Percentage
Districts	1,048	377	35.97
Schools	7,378	1,088	14.75

Source: Market Data Retrieval.

A study conducted by Carl Stutzman of California State University, Fresno, "Computer Supported Instruction in California Elementary and Secondary Schools," showed that the percent of schools using computers during the school year ending June 1980 totaled 36 percent for all schools and included 18 percent in elementary school districts, 61 percent of the secondary school districts, and 56 percent of the unified school districts.

The report also showed that the instruction areas receiving the most computer support were mathematics, computer literacy, science, business education, and career guidance. In the elementary districts, language

development and gifted programs also received a high level of computer support.

Two other notable findings in Stutzman's report were that the majority of teachers in California schools using computers are either without preparation or inadequately prepared in the use of computers in instruction and that the lack of financial resources is the primary inhibitor to the implementation of computer-supported instruction, followed by inadequately prepared faculty. (Stutzman, 19880) See Table VI-2.

TABLE VI-2

PROBLEMS INHIBITING DEVELOPMENT OF COMPUTER-SUPPORTED INSTRUCTION IN CALIFORNIA ELEMENTARY AND SECONDARY SCHOOLS DURING SCHOOL YEAR ENDING JUNE 1980

Problem	Percent of Responses			
	Elementary	Secondary	Unified	Total
Lack of financial resources	46.5	48.8	49.1	48.4
Inadequately prepared faculty	30.2	26.2	25.7	27.0
Lack of program director	14.0	14.3	13.2	13.6
Lack of space	5.8	3.6	5.4	5.0
Other	3.5	7.1	6.6	5.9
Duplicated Response Total	86	84	167	337

Source: Stutzman, Carl, 1981.

Computers are eventually expected to find their way into nearly every part of the school curriculum. Traditionally, the most popular use for a

classroom computer has been to teach students computer literacy — what computers do and how to use them. Now, there are more complicated programs designed to enhance higher reasoning skills in many disciplines, from improving a student's ability to create compound and complex sentences to basic math instruction. The way educators are using computers to improve education usually falls into five major categories.

- Drill and Practice -- Inexpensive if used on a massive scale. Provides instant feedback to student's reply. Good with basic skills of spelling, typing, vocabulary and math drills.

- Computer Assisted Instruction (CAI) — The computer teaches a concept, tests it, and loops back portions of the instruction as it is needed. It remembers the positions of each student and keeps records of individual progress. Tends to be expensive.

- Computer Manager Instruction — The computer gives short tests and assignments based on the student's performance, keeping records of each section. Instruction takes place without the machine.

- Simulation Programs -- Presents real-life situations that require basic math calculations to achieve a specified goal. Lemonade, a program for Apple, is an example. Students run a lemonade stand, making decisions about production, selling price and advertising. At the simplest level, a student must keep expenses within a budget. More advanced students try to maximize return on investment by understanding the mechanism of supply and demand.

- Demonstration Programs -- Help the teacher reinforce concepts. One program uses graphics to represent fractions. Another draws polygons, while a third leads the student step by step through a given concept; the long-division algorithm, for instance. (Wagner, 1981)

In his paper on technological changes in education during the 1980s, Stanley Pogrow, a Professor of Education at the University of Arizona, described two approaches that can be used to incorporate technology into educational delivery systems. The first approach he labeled the low-leverage system, or technology used to support and supplement the traditional activities of the teacher.

> Under a low-leverage delivery system, technology would be used in the classroom to help deliver some of the instructional activities that do not require constant teacher intervention. In other

> words, computers would enable students to engage in self-service learning activities much as the adult uses automatic tellers. Computers would also be used to assist the teacher in classroom management activities and student diagnosis. The goal would be to increase the amount of intensive educational activities available to students while freeing teachers to concentrate on those types of interactions which are uniquely human. (Pogrow, 1982)

Pogrow predicted that low-leverage delivery systems will be feasible by 1985.

The second approach, referred to as a high-leverage system, is described by Pogrow as technology used to supplant the role of teacher, where educational courses and activities are delivered directly to the home or classroom without intervention by an on-site teacher. This form of delivery system would seek to use technology to minimize the ratio between the number of people required to deliver educational services and the number of people served. There are two basic types of high-leverage strategies that can be envisioned; home-based and school- or community center-based. Pogrow stated:

> The prototype of the successful high-leverage system is Sesame Street. Schram (1977) and Jamison, Klees and Wells (1978) have demonstrated the cost effectiveness of high-leverage media such as radio and TV. The major educational limitation of these media, however, is that they do not provide the opportunity for interactive responses. (Pogrow, 1981)

According to those who design and sell computers for education, as students acquire a new set of learning skills and as computers become more sophisticated in their programmming, there will be effects on student achievement and speed of progress. It is too early to measure any possible improvement on a large scale, although several measurements on the local school district level have been published. One such test was conducted by

William Wagner, of the Santa Clara County Office of Education. He published a report that showed a group of fourth graders who received daily 15-minute sessions in computer-assisted drill and practice as a supplement to their regular math studies scored significantly higher on a standardized post test. The test was conducted at Fremont School in California during the 1979-80 school year. The school (in Hollister) purchased eight Apple II computers in 1979, for the purpose of improving the teaching of basic math skills. A computer center was established within the school and an aide was hired to assist the teachers and work with the students. The two math drill programs were "Math Facts," a set of 23 programs to drill on basic facts, from single-digit addition (two plus three = ?), through single-digit division; and "Math Levels," a set of programs coordinated with a textbook series. Students alternated each day between the two program types. About 150 students participated in the study, 80 percent of whom were third graders. Of the 26 pairs of students who had been matched on pretest scores, members of the experimental groups exceeded the corresponding members of the control group in 20 instances. Converting the raw scores on the post-test to grade level equivalents, the scores represented an average grade level of 4.7 and 3.9, respectively. Thus, it may be argued that CAI brought the students almost up to grade level, a growth of almost two years in one, while the control group remained a year behind. The results of this small study should be encouraging to teachers and administrators wishing to verify that computers can make a difference in improving performance in basic skills of students who are below level. (Pitschila and Wagner, 1980)

Administrators, teachers, parents, and students are having varied reactions to computers in the classroom, from initial acceptance to reserved optimism to downright rejection. Faculty in particular may be reluctant to use any technology in the classroom, according to industry officials, for

fear they will be replaced or from a lack of specific knowledge about computers. For these reasons, one of the key elements for the future use and success of computers in education is going to be faculty in-service training.

In his paper, Pogrow cited the seven most prominent barriers impeding the large-scale use of computer technology in the classroom.

- Inadequate capital resources for schools to purchase computers
- No incentives for teachers to use computers
- Lack of computer literacy among existing teachers and administrators
- Shortages of graduates with technical majors entering education
- Political resistance by teacher unions
- Lack of incentives or profit opportunities for industry to develop educational software
- Inadequate protection against software piracy. (Pogrow, 1981)

Marc Tucker, a former National Institute of Education policy director, quoted in February 2, 1982 Education Week, said, "Teachers have very weak incentives to use new technology. They are compensated for time-in-service and earned professional education credits, rather than for output." Tucker believes that, as a result, teachers may not be interested in the increased educational efficiency he thinks technology could bring. "You have to look at it from their viewpoint," he said. "To really integrate computers into the curriculum, you'll have to vastly change it and that's not easily done. ... A good deal of computer aided instruction will require more, not less, attention." (Toch, 1982)

VII. EDUCATION FOR HIGH-TECHNOLOGY INDUSTRIES IN OTHER COUNTRIES

Many nations outside the United States consider the achievement of scientific and technological superiority not only a major goal in itself but also an important aspect of competing with and succeeding over other countries. Different countries go about this preparation in various ways, including educating a substantial majority of their secondary school population to a point of considerable scientific and mathematical literacy.

While the United States has some current shortages and possible future shortfalls in engineering and the computer professions, the Soviet Union, West Germany, and Japan are producing much larger proportions of engineers and applied scientists than we are. Although their national policies promote education and training in these areas, far fewer numbers of people are expected to actually be working in the science and math-related professions than are trained for them. In the Soviet Union and Japan especially, managerial positions in both government and industry are heavily populated by people with engineering degrees.

Soviet Union

In the case of the Soviet Union, science and technology are viewed as important instruments in the struggle between socialist and capitalist systems. In formulating their tenth Five-Year Plan (1976-1980), Soviet leaders put a tremendous emphasis on "the acceleration of scientific-technical progress, the rise in labor productivity, and the improvement in the quality of work by all possible means in all sectors of the national economy." Since that time, the country has made large steps in its goal of

raising the quality of its workforce to bring about the scientific and technological transformation of the economy. (Ailes and Rushing,1981)

The USSR's commitment to the restructuring of skill levels is clear from the difference between the US and USSR when comparisons are made of the number of students enrolled in and completing programs as well as trends in the number of scientists working in the research and development fields in both countries. In 1950 there were roughly the same number of engineers in both countries. By 1974, the USSR had over twice the number of engineers as did the United States. See Table VII-1. This gap can be seen in the number of bachelor degrees conferred in both countries. The United States granted 37,000 engineering degrees in 1960, already surpassed by the USSR which conferred 102,900 degrees that year. See Table VII-2. (Ailes and Rushing, 1981) A recent New York Times article stated that the number of engineering students graduating in the USSR is now 300,000 compared with about 60,000 in the United States.

TABLE VII-1

U.S. AND U.S.S.R AVERAGE ANNUAL RATE OF GROWTH OF SCIENCE AND ENGINEERING MANPOWER: 1951 TO 1974
(In percent)

	Engineers	
	U.S.	**U.S.S.R.**
1951 to 1955	8.1	8.4
1956 to 1960	5.9	13.7
1961 to 1965	3.9	7.5
1966 to 1970	2.5	8.8
1971 to 1974	0.4	7.9
1951 to 1974	4.3	9.3

Source: Ailes, Catherine; Rushing, Francis W., 1981.

TABLE VII-2

U.S. BACHELOR'S DEGREES AND U.S.S.R. DIPLOMAS CONFERRED BY HIGHER EDUCATIONAL INSTITUTIONS
BY MAJOR FIELD OF STUDY: 1960-1979
(In thousands)

Year	1960		1965		1970		1975		1976		1977		1978		1979	
	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.
All Fields, Total[1]	394.9	343.3	538.9	403.9	833.3	630.8	987.9	713.4	997.5	734.6	993.0	751.9	997.2	771.5	NA	790.0
Science and Engineering Total	89.4	162.5	109.2	211.8	147.6	328.5	161.4	370.9	164.4	383.4	168.7	397.9	174.0	407.7	NA	416.9
Physical and Life Sciences and Mathematics[2]	45.3	(25.1)	65.7	(25.6)	91.4	(39.7)	96.5	(44.9)	98.2	(46.3)	97.5	(47.8)	95.3	49.0	NA	49.8
Engineering	37.8	102.9	36.8	152.3	44.8	230.5	47.3	272.1	46.7	280.4	49.7	291.4	56.0	300.1	NA	306.8
Agriculture	6.3	34.5	6.8	33.9	11.4	58.3	17.6	53.9	19.5	56.7	21.5	58.7	22.7	58.6	NA	60.3

Percent of 22/23 Year Old Population[3]

Year	1960		1965		1970		1975		1976		1977		1978		1979	
	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.
All Fields, Total	17.6	7.8	18.1	13.3	23.9	19.3	26.0	16.4	25.6	17.1	25.1	16.8	24.9	16.2	NA	16.4
Science and Engineering Total	4.0	3.7	3.7	7.0	4.2	10.1	4.3	8.5	4.2	8.9	4.3	8.9	4.3	8.6	NA	8.7
Physical and LIfe Sciences and Mathematics[2]	2.0	(0.6)	2.2	(0.8)	2.6	(1.2)	2.5	(1.0)	2.5	(1.1)	2.5	(1.1)	2.4	1.0	NA	1.0
Engineering	1.7	2.3	1.2	5.0	1.3	7.1	1.2	6.2	1.2	6.5	1.3	6.5	1.4	6.3	NA	6.4
Agriculture	0.3	0.8	0.2	1.1	0.3	1.8	0.5	1.2	0.5	1.3	0.5	1.3	0.6	1.2	NA	1.3

[1] Includes first professional degrees for U.S.

[2] Figures for the U.S.S.R. are estimates based on two-thirds of graduation in "university specialties" to which graduation in geology-prospecting, geodesy-cartography, and hydrology-meteorology have been added to approximate U.S. definitions.

[3] Percent of 22 year olds for the U.S. and 23 year olds for the U.S.S.R., due to differences in average length of years required to graduate from higher education.

Sources: Earned Degrees Conferred, National Center for Education Statistics, Department of Health, Education and Welfare, Annual Series;
National Economy of the U.S.S.R. in 1970, p. 646 and 1979, P. 500;
U.S.S.R. population data from Foreign Demographics Analysis Division, US Bureau of Census;
U.S. population data from Population Division, U.S. Bureau of Census. As cited in Ailes, Rushing, 1981.

The following facts about education and training in the USSR also make the picture clearer:

- The level of educational attainment of the Soviet population as measured by the number of years of technological-related training completed has risen from 5.8 years in 1960 to 8.7 years in 1977 and is projected to rise to 9.9 years in 1985.

- United States elementary school students (K-6) receive slightly more hours per week in science training than Soviet elementary students but total hours devoted to math at these grades is considerably below the average for the Soviet Union. See Table VII-3. (Ailes and Rushing, 1981)

TABLE VII-3

	US	USSR	US	USSR
Grade Range	K-3	1-3	4-6	4-6
Mathematics	3.2	6.0	3.7	6.0
Science	1.6	1.0	2.9	2.3
Social Studies	1.8	-	3.3	1.7

Source: Ailes, Rushing, 1981.

- The Soviet secondary school curriculum is accelerated in both science and math compared with curricula in U.S. high schools.

- The USSR has developed a specialized school that provides applied technical training at the secondary education level and is the principal source of the technical cadre that works under the direction of graduates of higher education, particularly in the engineering fields. Over one million students graduate from specialized secondary schools annually. There is no broad-scale equivalent type of training in the United States.

- As a percentage of college age population in 1978, the United States had nearly three times the number of students enrolled at higher educational institutions as the Soviet Union and one and a half times as many total graduates of the 22 to 23 year old population. However, in the engineering fields, the USSR graduated almost six times the number of specialists at the undergraduate level as did the United States, a difference which is substantial.

- About 70 percent of Soviet graduate enrollment is in the science and engineering fields. The percentage of total U.S. masters and doctoral enrollment in these fields has been steadily declining since 1960 and was about 20 percent in 1976 compared to 30 percent in 1960.

- In only ten years, the Soviet compulsory program for all students covers the equivalent of at least 13 years of American schooling of arithmetic, algebra, and calculus.

- From the fourth grade on, math is taught by a specialized math teacher whose training is equivalent to at least a master's degree program in the United States. (Ailes and Rushing, 1981)

In their book The Science Race, a summary of Soviet and American forecasts for the supply and demand of engineers in the future, Catherine P. Ailes and Francis Rushing conclude:

> The two countries' objectives and their models are quite different. Neither country has refined forecasts capable of producing accurate predictions of the full range of scientists and engineers. The consequence of this, however, seems to weigh heavier on the Soviet Union, where there is a command economy and where effective planning based on accurate information and reliable forecasts is essential. ....The Soviet Union is about to enter a period in which demographic factors will impose a constraint on its ability to increase the stream of new science and engineering entrants into the labor force. The 'over-supply' hypothesis could also be simply a reflection of the nature of the system to stockpile in advance of requirements to ensure the availability of supplies when they are needed. (Ailes and Rushing, 1981)

West Germany

Science begins in the third grade in West Germany with biology one to two hours a week. In the fifth grade, chemistry and physics are beginning to be taught as laboratory courses. All three sciences are taught two to three hours a week in that grade and geometry is introduced. The study of algebra begins in the seventh grade.

The basic secondary school education in West Germany seems to be so complete that students who specialize in such diverse areas as classics, math, or modern languages may pursue a degree in engineering at the higher educational level and thus compete with students who have a more technical background. There is a standard curriculum in West German schools that stresses science and math for all students through the tenth grade. If a student maintains good grades, he may continue through upper secondary school grades 11 to 13. Roughly 75 percent of those graduates go to universities and about one third of those receive degrees in science, engineering, and math. The most current data show that 224 bachelor degrees were awarded in computer sciences 11,241 in engineering, and 8,058 in postgraduate engineering. (Walton, 1982)

Overall, there is a high level of science and math among college graduates as well as a strong understanding of science and math among the general population in West Germany. This provides them with the basic tools to continue their education (German law guarantees that all people are entitled to a free education to as high a level as they desire as long as they maintain the required grades) at a later point in their careers which many choose to do.

The system in West Germany has undergone substantial changes in recent years due to the larger numbers of students (240,000 in the mid 1960s to 930,000). There has been a switch in the type of engineer in the country, meaning that industry has found it increasingly difficult to recruit the right mix of people. Students are tending to go into more specialized fields in recent years and not enough students are trained to be generally oriented engineers.

About 20 percent of qualified engineers are working in sales and commercial functions in West Germany. A current issue being debated is whether the pattern of engineering education should be adapted to reflect the type of work that German engineers are increasingly entering.

Japan

The Japanese approach to engineering appears to be almost totally market-oriented compared with most other nations. The philosophy of product development tends to work backwards from the identification of a market need or gap and the appropriate price of the product to meet the identified specifications. The specification is entirely in terms of market requirements, minimum costs, maximum reliability, and required performance. The role of engineering is perceived by engineers and management alike as the lynchpin. Thus, there is a logical and clear idea to the Japanese approach to engineering which is evident in the method of training. (Finniston, 1980) In terms of numbers, with a population about half that of the United States, Japanese universities graduated nearly 87,000 engineers last year compared with 63,000 bachelors degrees granted in the United States. Twenty percent of all baccalaureate and about 40 percent of all masters degrees are granted to engineers in figures which have been stable for the past ten years. This compares with a figure of about five percent at each degree level in the United States. (Kirst, 1981)

In Japan today, "science education does very well," according to Kay Michael Troost, an assistant professor of sociology and anthropology at North Carolina State University. " Science is perceived as interesting as well as useful. The Japanese do not have an elite view of science. They think that everyone should learn science." (Walton, 1982)

The Japanese curriculum Troost said, also places heavy emphasis on activities, field trips and experiments -- for primary grade students. These activities are closely tied to the texts used in the class. For the first six years of school, students spend about one-third of their time participating in "hands-on" activities. (Walton, 1982)

The NSF study came up with several statistics concerning math and science literacy in Japan. Among them:

- Japanese officials point out that students view the engineering degree as a "ticket" to business and social success in much the same way as the liberal arts degree (and now the MBA degree) was viewed in the United States two generations ago.
- The large number of Japanese students who enter scientific fields is made possible by a secondary educational system which has a heavy emphasis on science and math. There is a national guideline for lower secondary (seventh to ninth grades) which calls for about 25 percent of class time to be spent in science and math courses.
- College-bound students take math every year in high school and attain a level of sophistication beyond trigonometry. Only 10 percent of the students in the United States study trigonometry.
- Overall achievement scores in Japan in science and math are the highest in the noncommunist world, particularly with respect to problem solving skills.
- The Japanese school year is 240 days long compared with 180 days in most United States school districts. (National Science Foundation/Department of Education, 1980)

The Japanese course is normally four years in length. The initial two years provide a general education, based in engineering science but including humanities and foreign languages. The final two years of "professional education" are geared to build a student's knowledge of a particular area but there is widespread criticism in Japan that Japanese students learn only abstract sciences with an emphasis in theory and principles. As a result, engineering students gain little or no practical

laboratory experience like their American counterparts although tentative steps between education and industry are being taken to bridge that gap.

Japanese managers are increasingly critical of what they see as a woeful inability of the nation's technical schools to produce engineers equipped to take their place in industry. "It is not that education has worsened," said Yoshimochi Tamura, deputy director of the Education Ministry's Higher Education Bureau in Business Week. "but the technical level and demands of the Japanese industry have grown so much that it is now much harder for our educational system to meet corporate needs." (Business Week, 1981)

According to a report of the Committee of Inquiry into the Engineering Profession commissioned by the British Parliament in 1980 presented by Sir Montague Finniston, the level of output of qualified technical manpower in Japan is due to two main factors:

> First it reflects the intrinsic popularity to the school leaver of technical subjects compared with other areas of study. Engineering is much more popular than pure science and is the largest subject within higher education. Secondly, it has been brought about by the deliberate Government policy of expanding the number of places at university engineering schools. Given the competition for university places this has been sufficient to increase the supply of qualified engineers. The main expansion of engineering education occurred during the 1960s during which period the proportion of the work employed force employed in technical and engineering areas rose by 160 percent, a significant shift in the pattern of employment. We were told that around half of all engineering graduates entered manufacturing to work as engineers. The current level of supply was sufficient to meet industry's demand and was not likely to be expanded further. (Finniston, 1980)

VIII. EDUCATION FOR HIGH-TECHNOLOGY INDUSTRIES IN OTHER STATES

Preparation for the technology era is increasing in many aspects in other states as well as other countries.

State Governments and Education

In describing some of the activities in other states in their efforts to prepare students, one must first consider the relationship between the political and educational worlds. General government interest in education exists at various levels in a number of states. A recent report published by the Rand Corporation on State Involvement in Local Educational Quality Issues found that the degree of government involvement in education corresponds almost directly with the level of State Education Agency (SEA) activity.

In most states that have a moderately high level of government participation, the study found, interest is in the state's legislature. In a number of states, legislative interest was spurred by school finance debates. For example, in Maryland, New Jersey, Connecticut, and Florida, new state "quality improvement" legislation was a direct result of legislative consideration of change in school financing formulas. In other states, Virginia, Georgia, and Tennessee, new quality legislation and support for expanded SEA activities was a political response to constituency demand for increased accountability and citizen dissatisfaction with schooling outcomes.

The study, which did not include California, also concluded that gubernatorial involvement in public education is less common. However, the study said that where it exists, gubernatorial involvement has "served to

energize public education and define an active substantive role for the SEA." Governors in North Carolina, South Carolina, and Alabama all campaigned on a platform of educational improvement and have initiated ambitious new programs to advance educational quality in their states. The Southern governors tied educational improvement to their economic development goals, arguing that the state can neither attract new industry nor retain existing industry without schools capable of producing a well-educated working force. (McLaughlin, 1981)

Several states have been increasing their efforts to improve science and math education and prepare for future trends in various ways. Following are some examples of how they are going about it.

North Carolina

Under Governor James Hunt, the education system in North Carolina has undergone several changes which recently have led to an increase in the state's achievement on national tests. These changes have included competency testing, primary level training, reduced class size, and a new testing program for students and teachers. More recently, in regard to science and technology, Governor Hunt revived the North Carolina Board of Science and Technology, a 15-member board comprised of scientists from public and private institutions and officials from state and local government, which bring together the educational community and private industry. (Lindsey, 1982)

Together with the State Department of Public Instruction, the Board has developed a comprehensive progam aimed at halting the declining science and math performance. The program includes: 1) supporting experimental

programs of improvement at selected schools or school districts in the state; 2) providing funds to support physical science and mathematics teachers in attending college courses in those fields, and 3) trying to increase salaries of math and science teachers who are leaving the teaching field to go into private industry for higher salaries. (North Carolina Board of Science and Technology, 1981)

Also under Governor Hunt, the North Carolina School of Science and Mathematics has been established. It is a residential public high school for students with high aptitudes for science and math now in its second year with 300 students. In its first year with 150 students enrolled, the school had the second largest number of 1982 National Merit Scholarship semi-finalists of any school in the nation. Many of the students who took the Educational Testing Service's advanced placement examinations achieved the highest score possible. The school, according to its director of development, H. Braughn Taylor, " is part of the statewide campaign to transform North Carolina from a rural into an industrial — although not necessarily urban -- economy and to attract industry to smaller communities." (Walton, 1982) Students are expected to take at least one course in each of the areas of biology, chemistry, and physics. Courses offered include organic chemistry, analytical chemistry, two levels of physics as well as some physics electives (astrophysics and modern physics). In math, the courses range from an accelerated second year algebra to the highest level of calculus.

Minnesota

The Minnesota Education Computing Consortium (MECC) has helped establish Minnesota as probably the leading instructional computer state in the country. It is an organization created by the four public educational systems in Minnesota to coordinate and provide computer services to students, teachers, and educational administrators throughout the state. It was established in 1973, has a full time staff of 65 and is governed by a 16-member Board of Directors. Member systems of the consortium include: the Minnesota State Department of Education; the University of Minnesota; the Minnesota State University System, and the Minnesota Community College System.

MECC started offering statewide instructional computing services in 1974. The time-share computer communication network installed that year has grown into the largest network of its kind in the world.

All the state's colleges and universities and more than 76 percent of its school districts currently use instructional computing. As a tool to strengthen reasoning and problem solving skills, computing facilities are available to more than 95 percent of Minnesota public school and college students.

IX. WOMEN AND MINORITIES IN HIGH-TECHNOLOGY INDUSTRIES

The women's share of bachelor's degrees in engineering has risen dramatically in the last 10 years, but figures recently published in Science magazine show they still have higher unemployment rates and lower salaries than men in all fields of science and engineering, at all degree levels and at all levels of experience. Graduate enrollments indicate a continuing increase, at least through the next several years, in degree awards to women; but their access to equal employment and achievement opportunities is not assured. The women's share of bachelor's degrees in engineering has risen from less than one percent, in 1970, to 10 percent in 1980. At the doctorate level, as shown in Table IX-1, the number of science and engineering degrees awarded to women grew from 744, in 1965, to 4,099 in 1980. Among the principal findings of the National Science Foundation/Department of Education report on Science and Engineering for the 1980s and Beyond was a specific reference to women and minorities in these fields. The conclusion read:

> While considerable progress has been made by increasing the representation of minorities, women, and the physically handicapped, all three groups continue to be underrepresented in the science and engineering professions. (National Science Foundation/Department of Education,1980)

"These trends," wrote Betty Vetter, executive director of The Scientific Manpower Commission in Science, "suggest that the number and proportion of women will continue to increase, despite the impending drop in the 23- to 30-year-old population that will begin in the mid-1980s." (Vetter, 1981)

TABLE IX-1

NUMBER OF SCIENCE AND ENGINEERING DOCTORAL DEGREES AWARDED BETWEEN 1965 AND 1980

Year	All science and engineering fields	Physical sciences*	Engi-neering	Mathe-matical sciences+	Life sciences	Social sciences++
1965 Total	10,477	2,865	2,073	685	2,539	2,315
Women	744	127	7	50	263	297
1966 Total	11,456	3,058	2,299	769	2,712	2,618
Women	911	132	8	48	326	397
1967 Total	12,982	3,502	2,603	830	2,967	3,080
Women	1,086	161	9	48	401	467
1968 Total	14,411	3,667	2,847	970	3,501	3,426
Women	1,295	185	12	47	483	568
1969 Total	15,949	3,910	3,249	1,064	3,796	3,930
Women	1,472	205	10	56	537	664
1970 Total	17,731	4,400	3,432	1,222	4,163	4,514
Women	1,626	243	15	77	538	753
1971 Total	18,880	4,494	3,495	1,236	4,533	5,122
Women	1,929	244	16	96	656	917
1972 Total	18,940	4,226	3,475	1,281	4,505	5,453
Women	2,101	269	21	96	680	1,035
1973 Total	18,948	4,016	3,338	1,222	4,574	5,798
Women	2,446	257	45	119	795	1,230
1974 Total	18,316	3,696	3,144	1,196	4,407	5,873
Women	2,590	260	34	115	784	1,397
1975 Total	18,352	3,611	2,959	1,149	4,540	6,093
Women	2,838	284	50	110	863	1,531
1976 Total	17,872	3,442	2,791	1,003	4,480	6,156
Women	2,986	296	53	113	870	1,654
1977 Total	17,373	3,410	2,641	959	4,266	6,097
Women	3,103	303	74	128	845	1,753
1978 Total	17,956	3,234	2,423	959	4,887	6,453
Women	3,526	309	53	131	1,082	1,951
1979 Total	18,247	3,321	2,494	977	5,076	6,379
Women	3,854	351	63	145	1,190	2,105
1980 Total	18,171	3,151	2,479	963	5,325	6,253
Women	4,099	386	90	116	1,342	2,165

* Includes environmental sciences.
\+ Includes computer sciences.
++ Includes psychology.

Source: National Academy of Sciences. As cited in Science, 1981.

Some improvement in the disparity between women's and men's salaries apparently has been made, but a considerable gap still exists. After 1976, there was generally a wider gap between the salaries of men and women two years out of college than there was in the earlier part of the decade. As seen in Table IX-2, in 1980 there was a large gap in the median salaries of 1978 science and engineering graduates by sex. The largest of those fell in the math/statistics field, where men at both the bachelor's and master's degree levels earn $5,000 more than their female counterparts. Overall, in science and engineering at the bachelor's degree level, males earn $16,900, while females earn only $12,500; and at the master's level, males earn $21,900, while females earn $14,300. In 1980, the difference between men and women with 10 years of experience was $2,160 in mathematics or statistics, $6,408 in chemistry, $4,800 in biological sciences, and $3,708 in engineering.

TABLE IX-2

MEDIAN SALARIES OF 1978 S/E GRADUATES* IN 1980

FIELD OF DEGREE	LEVEL OF DEGREE AND SEX			
	Bachelor's Degree		Master's Degree	
	Male	Female	Male	Female
All Science and Engineering	$16,900	$12,500	$21,900	$14,300
Physical Science	14,400	13,100	19,300	17,900
Mathematics/Statistics	17,000	12,100	20,300	14,100
Computer Specialties	19,000	19,100	26,500	22,300
Engineering	21,300	20,700	25,000	23,000
Life Sciences	12,000	11,100	13,800	13,900
Psychology	9,500	9,900	15,400	12,500
Social Sciences	12,100	9,500	16,500	13,700

* Excludes S/E graduates who are enrolled full-time in graduate school.

Source: Division of Science Resources Studies, National Science Foundation. As cited in Scientific Management Commission, 1981.

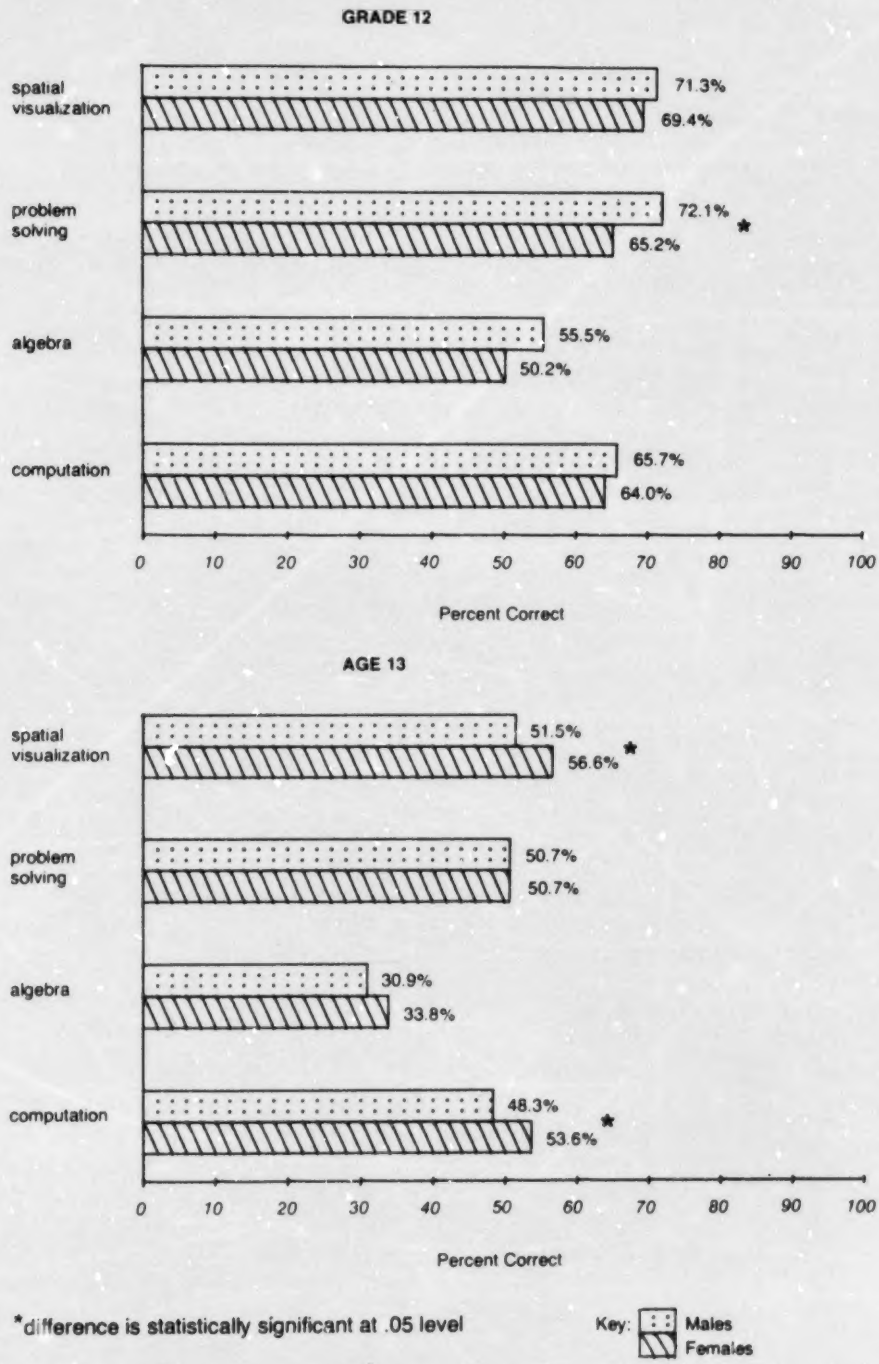
Although it is somewhat difficult to trace the reasons for the initial shortage and eventual increase in the number of women studying engineering and science, it is important to note some recent studies done on women's math and science abilities at an early age, as measured by test scores. The Education Commission of the States published a report in 1980, Achievement and Participation of Women in Mathematics, which found that 13-year-old females start their high school math career with at least the same ability as their male counterparts, as recorded in Figure IX-1. The report stated:

> In fact 13-year-old girls were proven to be better at computation and spatial visualization than males while their problem solving skills were nearly equal. By the 12th grade, males have overtaken the females. The hypothesis that males dominate math because they have a superior ability in spatial visualization was not supported by the study's findings. (Education Commission of the States, 1980)

Another study conducted by the California Assessment Program found that boys have lower math scores than girls at the third-grade level but slightly higher scores in the sixth grade and substantially higher scores at grade 12. Twelfth-grade girls again made greater progress than boys in math, continuing to narrow the gap at this grade. (California State Department of Education, 1981) Also at the high school level, the mean number of years of study for college-bound seniors differs somewhat by sex, with males taking more of these courses than females. In math, the difference is about one-third of a year, while in the physical sciences, it is closer to a year and a half. (California State Department of Education, 1980)

FIGURE IX-1

**Mathematics Achievement From the Women in Mathematics Survey, Fall, 1978.
Percentages of Correct Responses by Age and Sex**



According to the National Institute of Education's study on women in mathematics, three groups of variables appear to affect the participation of both boys and girls in math or science at the high school level and below. They are: 1) positive attitude toward math; 2) perceived need for math for future career and educational plans; and 3) influences of others, including parents, teachers and counselors. (National Institute of Education, 1980)

While women have made strides in the science and engineering fields, the same cannot be said for minorities. Ethnic and minority groups, except for the Asian Americans, are severely under-represented in these two fields. There is some indication, however, that the proportion has been increasing. In engineering, Black, Hispanic, and Native American enrollment was 5.7 percent of the freshmen class in 1973, and 8.03 percent in 1977. Minorities earned 10.9 percent of all Ph.D.s awarded to U.S. citizens and permanent visa immigrants in 1979. Among the minority doctorates, Asian Americans again dominated in the sciences. According to a recent Engineering Manpower Bulletin, of the nearly 63,000 graduates who received baccalaureate degrees in engineering in 1981, all minorities accounted for 8.3 percent, while Blacks, Hispanics, and American Indians, taken as a group, accounted for only 4.7 percent of the total. At the master's level, all minorities made up eight percent. Excluding Asian/Pacific Islanders, this drops to 2.6 percent. At the doctorate level, the corresponding percentages are 6.6 percent and 1.4 percent. (Engineering Manpower Bulletin, 1979) Table IX-3 shows the distribution of engineering bachelor's degrees granted in 1981 by curriculum and minority.

TABLE IX-3

MINORITY STUDENT REPRESENTATION AMONG DEGREES GRANTED IN ENGINEERING AND SCIENCE FIELDS

Proportion (%) of Degrees Awarded 1975-76

	Proportion in U.S. Population 1977	Engineering			Computer Science			Mathematics			Physical Science			Biological Science		
		BS	MS	Ph.D	BS	MS	Ph.D	BS	MS	Ph.D	BS	MS	Ph.D	BS	MS	Ph.D
Black	11.6	2.0	1.3	0.6	5.8	2.1	-	4.9	3.1	0.9	2.9	2.4	0.9	4.1	3.1	1.3
Hispanic	5.3	1.8	1.4	0.6	1.6	0.6	0.4	1.5	1.3	1.3	1.3	1.0	0.8	1.6	0.8	0.6
Native American	0.4	0.3	0.2	0.1	0.1	0.3	0.4	0.3	0.2	0.1	0.3	0.2	0.2	0.3	0.2	0.1
Asian American	1.3	2.1	3.0	4.2	2.2	2.6	1.6	1.9	2.4	2.3	1.5	2.6	2.5	2.2	1.9	2.5
Total Degrees Granted (Thousands)		45.6	16.0	2.8	5.6	2.5	0.2	15.9	3.9	0.9	21.2	5.4	3.4	54.2	6.0	3.4

Source: National Science Foundation, 1980.

Problems of access for minorities begin at the precollege level, in the science and math education they receive from early grades and on. Historical barriers, lowered expectations of teachers, and poor overall quality of training offered by schools, affect the students the most. According to a National Science Foundation study, once started in college, both Black and Hispanic students withdraw at a slightly higher rate than do white students at four-year institutions, and at a markedly higher rate at two-year institutions. Under all circumstances, the withdrawals are heavily (73-88 percent) for non-academic reasons, which suggests that economics play a significant role. (Engineering Manpower Bulletin, 1981)

Results of the SAT indicate large differences between majority scores and scores for the Black minority. Data recently released by the Educational Testing Service show that, during the five-year period from 1972-73 to 1976-77, Black students scored 119 points lower than whites on the verbal section and 134 points lower on the math section. Similar results were found on a variety of other standardized tests, including the NAEP math and science achievement tests. On the average, Hispanics often scored roughly midway between Blacks and whites. (National Science Foundation/Department of Education, 1980)

Other factors used by the California Assessment Program in measuring minority student test scores have been the language spoken by the student and the occupation of the principle breadwinner in the student's family. Chinese, Japanese, and Korean students fluent in English scored the highest of all minorities tested in mathematics in sixth grade. (California State Department of Education, 1980)

In a breakdown of the principle breadwinner in the student's family, test results show sons and daughters of executive, professional, and managerial wage earners scored dramatically higher, nearly 100 points in the mean score, than those of the unskilled or unemployed. (California Department of Education, 1980)

X. CALIFORNIA'S EFFORTS TO IMPROVE TECHNOLOGICAL LITERACY

Numerous efforts to improve California's readiness for the changing economy through programs aimed at elementary and secondary school students are already underway. In addition, as part of his "Investment in People" program, Governor Brown recently proposed several initiatives aimed at elementary and secondary school students. Numerous other possible actions have been proposed by educators and industry. Some of these current and possible future activities are discussed below.

Current Activities

Among the activities already underway in California to improve science, math, and computer literacy are these.

- Lawrence Hall of Science Computer Activities. The Lawrence Hall of Science at the University of California-Berkeley provides a wide range of activities for grades four through twelve and for teachers to improve computer literacy. Activities for students, available at the Hall or through visits by Hall staff to schools, include courses such as "Computer Games," "Introduction to Programming," "Creative Play," and "Computing Without Numbers". A hands-on workshop for teachers, "De-mystifying Computers," is designed to increase participants' awareness of the uses of computers in education. Thousands of students and teachers participate in the Hall's programs each year.

- The Mathematics-Engineering-Science Achievement Program (MESA). MESA, conceived in 1968, is a program designed to increase the number of underrepresented minorities in mathematics, engineering, and physical science-related professions by helping them to prepare for university-level programs in these areas. Headquartered at the Lawrence Hall of Science, MESA operates 15 centers that are affiliated with universities that have strong engineering and physical science departments. Each of the 15 centers works with nearby senior high schools and serves from 75 to 300 students. In 1982, MESA expects to reach 3,000 students. Activities conducted by the MESA centers include tutoring, independent study groups, career advising, field trips, summer enrichment programs, and scholarship incentive awards. More than 90 percent of MESA graduates have gone on to study at colleges and universities, two-thirds of them choosing majors in technical fields. (MESA)

- EQUALS. EQUALS, also headquartered at the Lawrence Hall of Science, conducts programs to help educators increase the participation of females in mathematics courses. The programs seek to train educators to do three things: teach math better, encourage students to continue the study of math through high school, and present the relevance of math education to career options. Since its inception in 1977, EQUALS has trained approximately 1,500 teachers, using mostly federal funds. Teachers have come from 65 school districts to receive 10 to 30 hours each of inservice training. (Kreinberg, 1981)

- Upward Bound. This program aims to provide disadvantaged students with career assistance and weekend and summer courses in science and math. The program now serves over 1,500 students in grades 9 to 12 at 20 sites statewide.

- Hewlett-Packard's Program. An Education Task Force was recently formed by Hewlett-Packard, a Palo Alto-based high-technology firm. One of the task force's objectives is providing students with practical information about science, math, and engineering,and information about career opportunities in the computer and electronics industries. Hewlett-Packard also conducts three youth emlployment programs, which provide students with the opportunity to work in trainee capacities in high-technology jobs. In one of the programs, the Summer Hire Program, the company hired over 830 youths in 1981.

- Computer-Using Educators (CUE). A California-based corporation, the purpose of this organization, which began in 1978, is to promote and improve computer use in schools and colleges. CUE has over 2,200 members in 39 states, four provinces, and 10 other nations. The organization's main activities are a bi-monthly newsletter, four major conferences a year, and SOFTSWAP, an educational software library and exchange. CUE's October 1981 conference attracted 1,400 persons. (CUE, 1981)

- Math Science Network. Established in 1974, the Math Science Network is composed of 1,000 scientists, educators, engineers, parents, community leaders, and business and industry people interested in technological literacy for women and girls. Its goals are to attract and retain females in math courses throughout their schooling, to encourage them to enter math-based careers, and to foster mobility and advancement for women in scientific and technical fields. Based in Oakland, the Network has conducted math and science workshops and conferences for females from kindergarten through the post-baccalaureate levels; developed handbooks for students, teachers, and women exploring science and math-based careers; pioneered programs to counteract math avoidance; and developed curricular materials for teachers. The Network's annual conference series that introduces secondary school young women to relevant math and science experiences and career opportunities is expected to draw 14,000 young women to 23 California college campuses, 17 campuses in the rest of the

country, and three campuses in Australia in 1982. (MacDonald, 1982)

- Individual Schools and Computers. As described in Section VI, California is one of the leading states in the number of computers that are used in classrooms, with nearly 36 percent of the school districts in the state having at least one microcomputer. Individual school districts are establishing uses for computers in their schools and planning for more. For example, the Rio Linda district in Sacramento County has a full-time district-wide computer coordinator, about 25 computers serving half its students, and plans to have computers in all its schools in the near future.

Department of Education Activities

Aside from six special schools for handicapped children, the State Department of Education does not provide direct instructional services to students. The Department does, however, provide a variety of technical and program services to schools and school districts and a number of these services either allow or encourage improved science and math education.

- The Department prepares and publishes, and the State Board of Education adopts, curriculum frameworks in several curricular areas, including math and science. Frameworks are supplemented by courses of study prepared by county offices of education. Both science and math frameworks have been revised in recent years to reflect renewed interest in science and mathematics instruction. (Wilson, 1982)

- Over half of the State's elementary schools and almost one-fourth of the secondary schools participate in the voluntary School Improvement Program (SIP) that began in 1978 and built upon the Early Childhood Education program that started in 1973. Schools involved in the program are required to have school site councils composed of school staff and parents. These councils prepare school plans that address school goals and strategies in all areas, including instruction in math and science. The councils oversee implementation of the plan and evaluate outcomes in order to revise the plan in following years. Goals, needs and strategies are locally determined through interaction with communities and are not directed by the State. The Department of Education reviews school programs and says that the SIP schools will be among those best prepared to respond to needs for mathematically, scientifically, and technologically literate graduates. The scores of students on standardized tests have risen faster in schools that participate in the program than in schools that do not. (Wilson, 1982)

- The Department traditionally has made a variety of curriculum and program specialists available to schools in need of assistance. In recent years, the Department also has developed local capacity to review, evaluate, and modify school and instructional programs. Through regional teacher resource centers, state-supported staff development programs (locally designed and based) and grants of innovative program funds, the Department has encouraged upgrading of teacher skills and new program development to improve the teaching of mathematics, science, and other curricula. (Wilson, 1982)

- In response to requests for more detailed curriculum improvement assistance, mostly from school site councils, the Department has produced curriculum handbooks in six curricular areas. The science handbook was published in March 1982 and the mathematics handbook is scheduled for publication in May 1982. Designed for use by both professional and lay persons, these handbooks go beyond the more traditional frameworks and provide guidelines for curriculum review, planning, implementation and evaluation. (Wilson, 1982)

- In order better to inform the current debate about strengthening high school standards and curriculum content, the Department currently is completing a study of high school curricula which centers on the following questions: 1) What is the nature and rigor of the high school curriculum (with emphasis on higher level courses in math, science, and English) today, as compared to five, ten and 15 years ago?; 2) What are factors that impede students' completion of courses required for graduation?; and 3) Have state proficiency requirements caused schools to reduce their higher level academic course offerings? A report on study findings is expected to be available in June 1982. (Wilson, 1982)

Governor's Proposals

Governor Brown, acting on the concern he expressed in his State of the State message regarding the need for California to be better prepared

for the growth of high-technology industries, has proposed "Investment in People" initiatives to the Legislature with the goal of improving technological literacy. The Governor has called for asking local school boards to require all high school students to take at least three years of math and two years of science. His 1982-83 budget includes funds for training teachers in math, science, and computer instruction; funds for bringing computers into schools; and funds for supplying the equipment needed to expand science instruction. In the area of teacher staff development, the Governor has proposed retraining existing teachers with credentials in math and science who are currently teaching in other areas; upgrading the math, science, and computer skills of teachers working in these fields through intensive summer institutes; providing resources to local schools to implement ongoing staff development strategies; and funding exemplary projects aimed at teacher development, curriculum improvement and increasing student's skills and motivation in technology-related fields.

Future Options

Numerous methods for improving technological literacy have been offered by educators, industry, government, and observers of the educational system. Many of these improvements build upon and complement the approaches taken in some of the exemplary programs in California and the approaches proposed in the Governor's initiatives. They include actions that affect teacher qualifications and abilities, student enrollment in math and science, and materials and curriculum.

In the area of teachers, the following activities are being discussed:

- Increase salaries to make teaching more competitive with other career options.

- Retrain recently laid-off teachers and teachers with credentials in math and science who are working in other subject areas. Employ them in science and math.

- Improve the instructional skills of teachers in order that they are better able to motivate students to persist in science and math studies, achieve in these areas, and pursue high-technology careers. The upgrading of skills could be accomplished through staff development centers operated by schools or colleges, direct assistance to local high schools, and/or teacher training projects.

- Upgrade the skills of teachers already working in math and science and develop mechanisms to keep them up to date in rapidly changing science and technology fields, including computers.

- Clearly inform teachers and guidance counselors of the skills needed to enter industry or voc-tech programs related to high-technology industries following high school.

- Develop incentive programs to attract students into math and science education programs, such as fellowships, scholarships, and loans.

- Identify secondary school teachers without credentials in math or science who wish to teach in these areas. Provide opportunities for part-time and/or summer school pursuit of the courses needed to quality for math or science teaching.

- Provide incentives, including financial incentives, for math and science teachers to remain in teaching, rather than to leave their positions for jobs in industry.

The following actions are among those available to encourage students to take more math and science.

- Increase math and science high school graduation requirements, the math and science components of college and university admissions requirements, and/or university graduation requirements in science and math.

- Encourage enrollment in advanced science and math courses by encouraging universities and colleges to take advanced courses into account in admissions decisions.

- Inform students specifically of the skills they will need to pursue college science, engineering, and computer science curricula and the skills they will need in nonprofessional, technically-oriented jobs, through contacts with industry,

universities and colleges, and guidance counselors, teachers, and students.

- Encourage elementary and junior high students who show interest and aptitude in science and math.

Following are some suggestions that have been made to improve materials and curricula:

- Increase instructional use of computers at the secondary level.
- Augment existing textbooks with more challenging materials.
- Establish curricula with courses and materials available to and appropriate for students entering both professional and non-professional high-technology-related jobs.
- Integrate science and technical subjects into other coursework.
- Provide field trips to and guest lectures from high-technology industries.
- Develop new courses and sequences of courses in sciences and math, including practical courses such as "Introduction to Electronics" and general courses like "Science, Technology, and Values."
- Encourage more collaborative programs between high-technology industries and schools.

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